Economic Sustainability of Extensive Beef Production in South Africa

By Ayanda Saki

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Supervisor: Dr. W.H Hoffmann

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Declaration

By submitting this thesis, I, A Saki, declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

A Saki March 2020

Abstract

Satisfying the increasing and changing demands for animal food products, while sustaining the natural resource base (soil, water, and biodiversity) and decreasing Green House Gas (GHG) emission, is one of the major challenges currently facing agriculture in the world. Livestock production is said to carry a large carbon footprint compared with other foods, with cattle being a major contributing source of CH4 emissions which accounts for approximately 72.6% of the total livestock GHG emissions. A number of studies have concluded that extensive beef production has more environmental demand compared to intensive beef production. However, beef in South Africa is produced at different levels or by different categories of farmers which are commercial and small holders or communal farmers. Each farm has its own resources and differs from other farms in many aspects, and no two farms will exactly have the same factors affecting its performance the same way.

The aim of the study was to measure environmentally sustainability of extensive beef production in South Africa, and to identify the category of farmers with more environmental demand relative to the other per kg of beef produced. To achieve these objectives typical farms were developed using secondary data and cost benefit analysis of the typical farms was performed. Indicators that were used to measure environmental demand were Green GHG emission, water use and biomass (fodder) consumption. Environmental demand was estimated for each production system (extensive commercial, extensive communal and feedlot beef production). Budget models of typical farms with three scenarios were developed with environmental demand expressed in monetary values and Cost Benefit (C/B) ratio was calculated to measure the environmental sustainability of each category of farmers. Production efficiency of different production categories of farmers was calculated to identify the farmers that are using resources efficiently (environmental costs per kg of beef produced).

The results show that the total demand for GHG emission and biomass are higher in commercial farmers than in communal farmers. However, when measured per kg of beef produced commercial farmer demand less GHG and biomass compared to a communal farmer. A commercial farmer demands more water per kg of beef produced than the communal farmer. The developed budget models showed that both commercial and communal farmers have more environmental demand compared to benefits and commercial extensive beef farmers are employing resources efficiently than communal extensive beef farmers.

Opsomming

Om die toenemende en veranderende vraag na diereprodukte te bevredig, terwyl die natuurlike hulpbron basis behou word (grond, water en biodiversiteit) en die kweekhuisgasse te verminder is een van die belangrikste wat boerdery wêreldwyd in die gesig staar. Lewende hawe produksie dra grootliks by tot koolstofvoetspoor vergeleke met ander voedselprodukte en beeste dra by tot CH4 vrystelling wat ongeveer 72.6% by tot die totale uitlating van kweekhuisgasse. Vele studies het die gevolgtrekking bereik dat ekstensiewe beesvleisproduksie ʼn groter bydra maak tot omgewings impak as intensiewe produksie stelsels. Beesvleis word in Suid-Afrika deur verskillende vlakke of kategorie van produsente produseer wat varieer tussen kommersiële en kleinboere. Elke boerdery het unieke hulpbronne kan verskil van ander boerderye en geen twee boerderye sal dieselfde uitkoms hê as dieselfde faktore dit beïnvloed nie.

Die doel van die studie was om die omgewingsvolhoubaarheid van ekstensiewe beesvleisproduksie in Suid-Afrika te bepaal en om die kategorie van produsente te identifiseer wat die grootste impak op die omgewing toon in terme van kg vleis geproduseer. Om die doelwit te bereik is tipiese plase ontwikkel deur sekondêre data te gebruik en ʼn kostevoordeel ontleding te doen. Die omgewingsaanwysers wat gebruik is was groen kweekhuisgasse, water gebruik en voergebruik. Die omgewingsvraag is geskat vir elke stelsel (ekstensief kommersieel, ekstensief kleinboer en voerkraal stelsel). Begrotingsmodelle vir die tipiese plase is ontwikkel vir drie scenario’s wat die omgewingsimpak in geld waarde uitdruk en die kostevoordeel faktor is bereken om om die volhoubaarheid van elke stelsel te bepaal. Produksie doeltreffendheid vir die verskillend kategorieë van boerdery is bereken om die hulpbronne benutting te bepaal (omgewingskoste per kg vleis geproduseer).

Die resultate wys dat die totale vraag na kweekhuisgasse en voedselgebruik hoër is vir kommersiële boere as vir kleinboere. Per kg uitset is die kommersiële boere egter meer doeltreffend. Kommersiële produsente se vraag na water is ook hoër as vir klienboere. Die modelle wys dat beide kommersiële en kleinboere se koste vir die omgewing hoër is as die voordeel en kommersiële ekstensiewe produsente benut beskikbare bonne meer effektief.

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1 INTRODUCTION

1.1 Background

Globally livestock production is the largest user of land resources with land and pasture dedicated to the production of animal feed representing almost 80% of the total agricultural area (Van de Merwe, 2011). According to Ridoutt *et al.* (2014) land resources are currently under stress, and with a world population projected to increase towards nine billion inhabitants by 2040, the increased demand for food and fibre need to be met in ways that do not lead to continued loss of natural ecosystems and expanding land degradation. The situation in South Africa is no different, approximately 80% of the country's terrestrial land surface area is utilised for agriculture, with almost 70% mainly suitable for raising livestock (Spies, 2011). This makes livestock production one of the most important farming practices in the South Africa.

Not only is it an important current sector, BFAP (2014) projected a further increase of 20% in beef consumption through the next decade. This implies that the local beef industry needs to increase beef production by about 11% per annum, which translates to approximately 20 000 to 30 000 tons of additional beef production per annum to supply the demand for local use and exports (Webb, 2013). This increase, however, would have additional environmental consequences on-top of the existing environmental demand. Such environmental demands include fodder and water consumption as well as the emission of greenhouse gasses (GHG's). These three concerns with respect to the environmental demand of beef production will be briefly introduced in this chapter and expanded upon later.

Domesticated livestock, directly or indirectly, produce GHG's such as carbon dioxide (CO_2) and methane (CH_4) along with small quantities of ozone (O_3) and nitrous oxide (N_2O) (Steinfeld, 2004). As a result livestock production has been recognised as a large contributor in agriculture to climate change (Picasso *et al.*, 2014). It is predicted that climate change will put more pressure on the country's scarce water resources, quality of land, and have negative implications for agriculture. It contributes to increasing seasonal variations and increases in the number of extreme events such as droughts and floods (FAO, 2013). Additionally, GHG emissions related to feed production is another contributor to climate change (Mogensen *et al*., 2014). Livestock farming, as any other sector is required to reduce GHG by 20% by 2025 to meet South Africa's global commitments to reduce such emissions (RPO and NERPO, 2014). This implies that measures to reduce GHG emissions are necessary to preserve long-term agricultural productivity and economic development.

Another factor of concern is that of water consumption. Global and South African water use estimates for red meat production vary from 80 to 540l/kg meat (Meissner *et al*., 2013b). Strong actions have to be taken to improve water management and increase water use efficiency. The reduction in cattle numbers are hardly an option given the increasing demand and population. The allocation of more water resources given the fact that the country is already water stressed is unlikely. Since the water footprint of cattle production depends on the type of production system and efficiency (Meissner *et al*., 2013b), it is important to differentiate among the systems to sought the most efficient system. The third factor of concern is related to fodder consumption. The loss in biodiversity and land degradation in the form of deforestation and overgrazing are also often linked to livestock production activities (Steinfeld, 2004). This is given the fodder demand of the cattle, whether produced commercially or naturally grown. Again, as is the case with water, the efficiency of fodder consumption is linked to the type of production system.

The study will investigate the economic sustainability for different categories of beef farmers under different production systems, with the main focus on extensive production systems. The different farming systems will therefore be discussed in relation to their implications for cattle management. The environmental demand versus benefits for each of category of farmers will be discussed with respect to fodder and water consumption and well as GHG emissions. This will be done to seek the category of farmers that are practising efficient beef production management systems.

1.2 Problem Statement

Satisfying the increasing and changing demands for animal food products, while sustaining the natural resource base (soil, water, and biodiversity) and decreasing GHG emission, is one of the major challenges currently facing agriculture in the world. Like any other human activity, livestock production has significant impact on the environment, depending on the form of livestock production system and method (Palermo *et al.*, 2014). Livestock production is said to carry a large carbon footprint compared with other foods. Cattle being a major contributing source of CH_4 emissions from the livestock sector in South Africa, approximately 72.6% of the total livestock GHG emissions (Du Toit *et al*., 2013). A number of studies have concluded that extensive beef production has more environmental demand compared to intensive beef production. However, beef in South Africa is produced at different levels or by different categories of farmers which are commercial and small holders or communal farmers and each farm is unique.

Sustainable agricultural practices are encouraged as the solution to the challenge. Sustainability is composed of three pillars social sustainability, ecological sustainability and economic sustainability. Economic sustainability emphasises growth and efficiency use of resources, whereas social sustainability is concerned about the extent in which society's needs are met and ecological sustainability focus is on environmental protection and altitude towards it (Barbie *et al*., 1989). Achieving sustainability requires recognition of the inter-dependencies between the natural environment, economic stability and social well-being (Nahman *et al.*, 2009). Is the South African extensive beef production sustainable? Which category of farmers or production level has more environmental demand and uses natural resources more efficiently relative to the other per kg of beef produced?

Sustainable agriculture is widely defined as production of food and fibre in ways that meet the needs of the current generation with the available natural resources without compromising the future generation to do so (Barbie *et al*., 1989). Sustainability is a question of intergenerational equity, asking about the fair or just distribution of productive capacity and welfare between the present and future generations (Farzin, 2007). The well-being of present and future generations crucially depends on how society uses its resources. The available resources in the society that are necessary to maintain social welfare over time can be described in terms of economic, natural, human and social capital. Capital is measured in terms of stocks, which are built up through investments (UNICE, 2014). The stock of capital may be interpreted as the combined total stock of manmade capital assets and natural assets or, more narrowly, as the stock of natural capital.

The narrow definition of the resource base in terms of natural assets only, does not dispute the importance of man-made capital in the sustainable development process, but emphasizes the non-substitutability of many natural resource functions by man-made capital (Barbier *et al*., 1987). Natural resources are used for a variety of purposes in economic processes and contribute to human well-being directly by providing an environment for living, recreation, leisure, etc. (UNICE, 2014). All generations depends crucially on the currently available stocks of manufactured capital, human capital, knowledge capital, and social capital. Developing counties are currently very poor in such assets, being more dependent on environmental and natural capital for their well-being (Farzin, 2007).

The society has limited natural resources to meet sustainability objectives such as economic growth, poverty alleviation and environmental protection. These sustainability objectives compete for resources and may conflict with each other (Panayotou, 1997). Increase in production to meet the growing demand of the animal protein may increase environmental demand and environmental regulations that are aimed at environmental protection may constrain growth (Babier *et al*., 2008). The more efficiently these resources are used and the better they are managed now, the more capital is left for people elsewhere on the planet and for future generations (UNECE, 2014). If efficiency is optimal, land use and resources are optimized and the carbon and water footprint are reduced. In order to improve efficiency all input variables (natural resource base, financial arrangements, human resources, inputs, skills, abilities and other factors such as social concerns) will have to be harnessed in support of biological measures in such a way as to ensure that the end product is the result of efficiency at all levels (Meissner *et al*., 2013b).

In a neoclassical approach and in terms of Pareto optimality, resource use is efficient when it maximizes the welfare of the society. The best known and used indicators to express efficiency include capital productivity, work productivity, allocation and consumption of natural resources, return rate and profit rate (Borza, 2014). Efficiency of livestock production can be measured in various ways, ranging from biological (off-take, feed efficiency) through sustainability of production to simple economical returns. The challenge is to achieve maximum economical returns through optimal biological production efficiency and maintaining long-term sustainability at the same time. Biological efficiency is arguably the most critical factor as it is partially under control of the farmer. One way by which biological efficiency can be evaluated is through percentage off-take or slaughter rate (Meissner *et al*, 2013b). However, in the case of extensive beef production where there is parent stock and the main focus in most cases is marketing of weaners, the most efficient manner is to measure the amount of input resources needed to produce a unit of beef and to keep the parent stock productive. To facilitate efficient allocation of resources cost benefit analysis (CBA) is recommended as a suitable tool. CBA has the advantage of balancing the beneficial aspects of a policy or project against the real resources society must give up to implement the policy or project (Panayotou, 1997). In answering the question of sustainability in South African beef production, the study will assess efficient use of natural resources (water and biomass) and greenhouse gas emission by extensive beef producers. The focus on natural resources and GHG emission does not dispute the importance of other capital assets employed in beef production but emphasizes the scarcity of these resources and the pressure to meet the growing protein demand and reduction of GHG emission at the same time.

1.3 Objectives of the Study

The primary objective of the study is to assess economic sustainability of extensive beef production at different production levels in South Africa.

Secondary objectives are:

- To evaluate greenhouse gas emissions and explore the possibilities to reduce it per unit of beef produced,
- To evaluate water use and explore the options to increase water-use efficiency by increasing the beef production per litre of water, and
- To evaluate the fodder consumption while seeking to reduce the grazing material required per unit of beef produced.
- To determine production benefits against environmental demand at different production levels

1.4 Significance of the Study

The livestock industry is facing the challenge of producing sufficient animal protein to supply the needs of the growing global population, whilst reducing negative environmental impact (BFAP, 2014). The world population is expected to grow to 9.2 billion by 2050. More than 60 % of people live in urban areas, meaning that global food production need to double by 2050. The world is threatened by erratic climate change patterns and natural scarce resources such as land and water are under pressure. It is important that natural resources are optimally utilised to the benefit of all current and future users and dependants. Sustainable agricultural practices are encouraged as the solution. Sustainable production methods in agriculture are production methods that can be used to produce the current demand of food and fibre without compromising the ability of the future generation to do so. Climate change cause temperatures to rise, reduce rainfall and change their timing. This puts more pressure on the country's scarce resources such as water and quality of land. Globally, agriculture is a key contributor to climate change, being responsible for about 14% of global total emissions (White Paper, 2011). Livestock production accounts for nearly 80% of the sector's emissions (McMichael *et al*., 2007) and cattle production is considered as the major contributor (Du Toit *et al*., 2013).

1.5 Proposed Research Method

The study will focus in the country's extensive beef primary production. Cost benefit analysis (CBA) of typical farms will be used as an assessment tool to determine economic sustainability of the sector. CBA is a systematic process for calculating and comparing benefits and costs of a project (Belli *et al*., 1997). CBA helps to predict whether the benefits of a project or decision outweigh its costs, and by how much relative to other alternatives. Its power as an analytical tool rests in the fact that the costs and benefits are expressed as far as possible in money terms and hence are directly comparable with one another. It is valued in terms of the claims they make on and the gains they provide to the community as a whole in current monetary value (Bizoza and De Graaff, 2012). The study will explain more about CBA under proposed methods and methodology chapter.

Extensive commercial and small scale/communal typical farm profiles will be developed using secondary data. A typical farm is a tool that can be used to assess farm profitability and to determine the effect of variations in a range of variables on farm-level profitability (Hoffmann, 2010). The concept of typical farms has been used since the late twenties and early thirties (Hatch *et al*., 1982). The typical farm model allows for the evaluation and comparison of the effect of various managerial decisions and options (Hoffmann, 2010). Environmental costs such as GHG emission, water use, and biomass consumption for the typical farms will be estimated and C/B ratio will be calculated.

1.6 Delimitations of the study

A number of studies have concluded that extensive beef production has more environmental demands compared to intensive beef production, and most of animals finished under intensive have been sourced from the extensive production farmers. Therefore cost benefit analysis will only be done on extensive production system. Sustainability has got three principles, namely; social, economic and environmental. The study will only focus on economic sustainability of beef industry. The objective of the study to assess the efficient use of natural resources and to measure benefits and costs in the society as whole not of an individual farm, therefore financial cost benefit analysis will not be considered only economic cost benefit analysis will be done.

1.7 Outline of the study

The thesis is organized into five main chapters. Chapter one is an introduction. This chapter provides a brief background of the study, problem statement, objectives, significance of this study, proposed research method and delimitations of the study. Chapter two provides descriptive overview of the beef industry and review of methods. Relevant literature on livestock industry, production systems, challenges faced by the beef industry, and sustainability of beef production is reviewed. Chapter three gives the description of materials and methods used in the study, cost benefit analysis and typical farm as an evaluation tool. Chapter four presents the methodology application, results and analysis of results. Chapter five is the conclusion, summary and recommendations.

2. INDUSTRY OVERVIEW AND REVIEW OF METHODS

2.1. Introduction

The importance of the agricultural sector cannot be overstated. This also applies to that of livestock production with beef cattle, dairy cattle, chickens, sheep and goats generating 92% of the total revenue from livestock in Africa (Rust and Rust, 2013). Its importance is unlikely to decline. The global demand for food and farmland is rapidly growing due to a variety of factors including growing human population numbers, increased meat consumption, urbanization, competing land uses for non-food crops and the alteration in the suitability of land to grow crops due to climate change. Efforts need to be made to increase the productivity of all production systems (communal, commercial, extensive and intensive) in order to supply the local demand for animal products (Webb, 2013). The main goal of this research project is to determine the economic sustainability of extensive beef production by conducting cost benefit analysis study. In support of this it is important to put the industry and the factors contributing to its sustainability into perspective. This chapter includes the livestock industry with special focus on extensive farming. It also includes an overview of the impact of production from ecological point of view. The chapter concludes by explaining the concept of sustainability and its application to the livestock production systems.

2.2. The South African Beef Industry

Livestock is the largest agricultural sector in South Africa, consisting of 13.8 million cattle and 28.8 million sheep. Livestock products contribute 27% of the consumer food basket on a weight basis. Consumption of livestock foods resembles that of developing countries with meat consumption being of 50 - 90g/capita/day, milk and dairy products 120 - 130g/capita/day and eggs 15 - 20g/capita/day (Meissner *et al*., 2013). Animal production contributes R96, 5 billion to the agricultural production gross value of R208, 3 billion (DAFF, 2015).

In addition to the meat, the other livestock products perform various beneficial to the health and welfare of households. These include provision of cash income from sales of animal products, nutrition from consumption of livestock products, fertilization of soil with the manure and draught power during planting times as most of the poor households does not own tractors (Mandleni 2011). About 2 125 000 people are dependent on the livestock sector, with beef industry as a major contributor. Commercial beef farmers are estimated at 22 000 and emerging farmers and communal farmers are estimated at three million. Emerging farmers and communal farmers employ nine million people and commercial farmers employ 138 000 people (DAFF, 2017).

2.2.1. Production

Total Cattle numbers have been above seven million since 1970 and increased in variable rates up to 13.6 million in 2014. The country experienced a decrease of population in some years as shown in Figure 2.1. Seventy eight per cent of the total cattle population in 1970 was beef cattle; the population has been increasing and decreasing throughout the years but always more than 78% up to 91% in 2014. From 1980 to 2014 an average of 41% of beef cattle was produced in the small scale and /or emerging sector and 59% within the commercial sector. Cattle population is distributed throughout the country. The Eastern Cape contain the largest population of about 24% of the total population, followed by Kwazulu Natal with 20%, Free State 16%, North West 12%, Mpumalanga 10%, Limpopo 8%, Western Cape and Northern Cape 4% each, and Gauteng 2% (DAFF, 2014). This is shown in Figure 2.2.

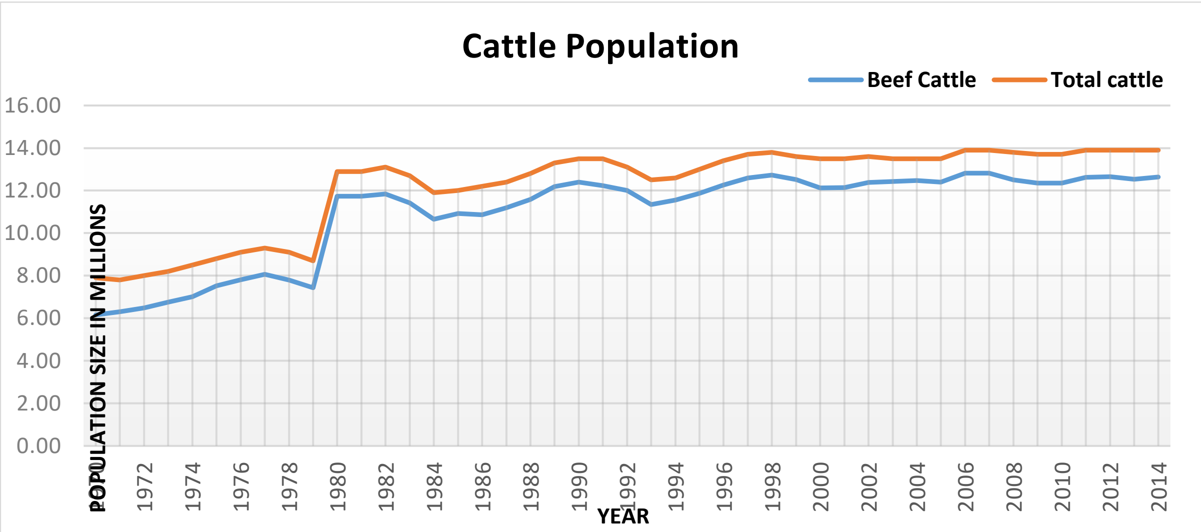

Figure 2.1: Cattle population in South Africa

Source: DAFF 2015.

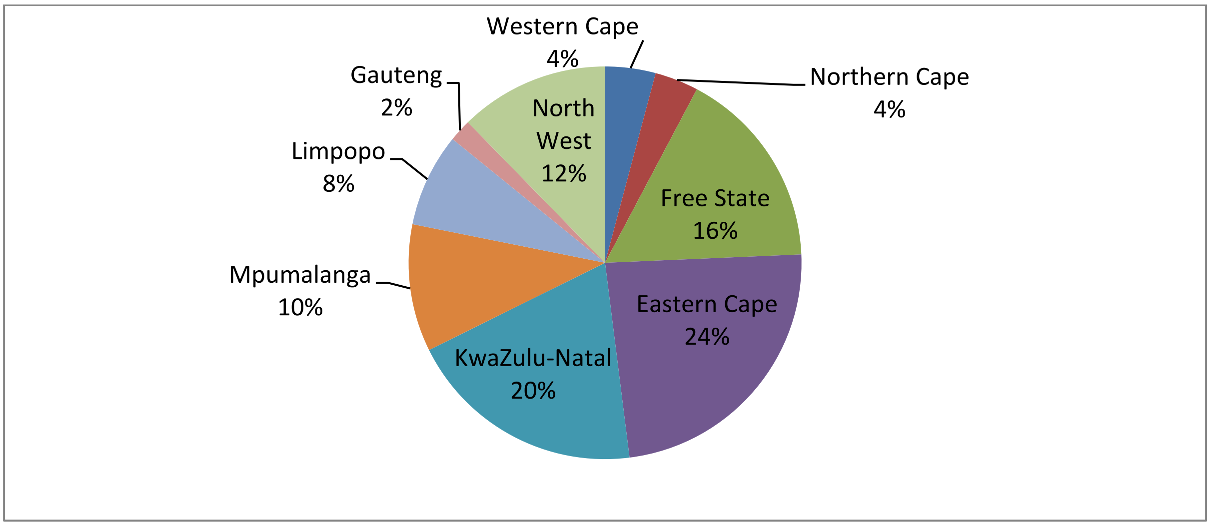

Figure 2.2: Distribution of Cattle in the Province of South Africa

Source: DAFF 2014.

2.2.2. Domestic beef consumption vs production

Currently the country does not meet the local demand for beef, while there are increasing opportunities to export to other African countries as well as the European Union (Webb, 2013). Both production and consumption followed the same trend, increasing from 1970 with slight decrease in some years. The decline is some years are usually associated with the global economic conditions which leads to a decrease in disposable income of large number of consumers. In the early 2000's, growing income levels, sustained trends of urbanisation and improved living standards supported dietary diversification in South Africa, resulting in the inclusion of more protein in typical diets and rapid growth in meat consumption. In more recent years however, economic performance has dwindled and in real terms, consumer incomes have come under pressure, resulting in slower overall growth in meat consumption (BFAP, 2018). As the economy recovers from recession beef production and consumption increases (DAFF, 2017). South African beef imports have been decreasing as the production increases. In 1970 the country was importing 26% of 549 000 ton of total beef consumption and imported 2% of 981 000 ton of total consumption in 2014. The country's per capita beef consumption has been moving in the opposite direction to that of consumption and production, decreasing gradually from 24.15 kg in 1970 to 18.51 kg in 2014. The trends are shown in figure 2.3.

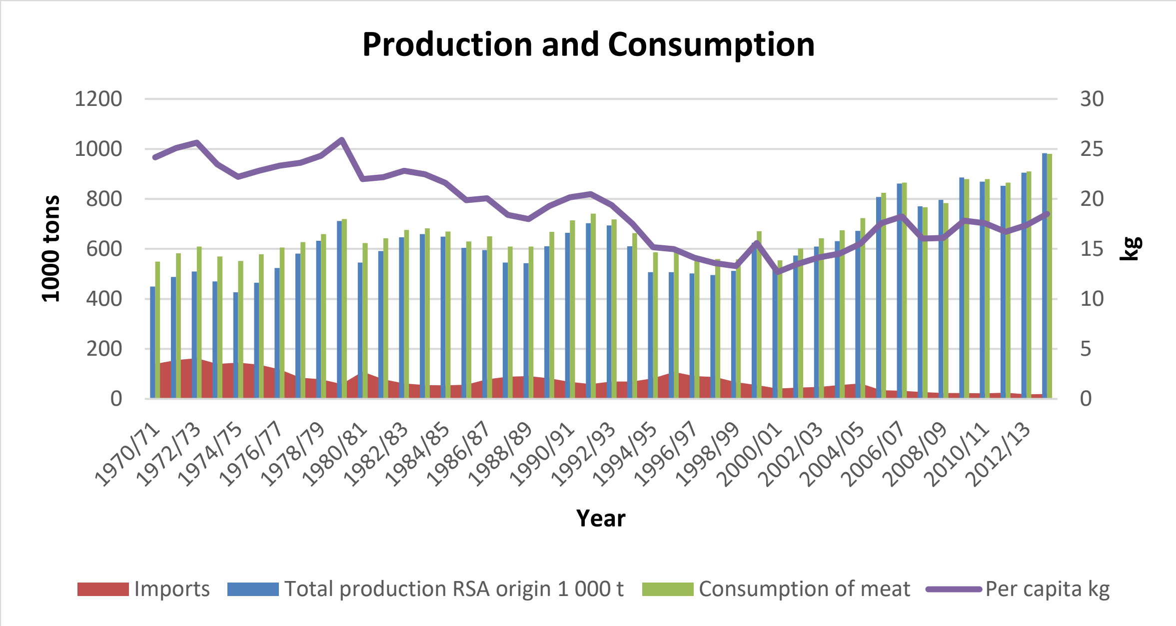

Figure 2.3: Consumption and Production from 1970-2013

Source: DAFF 2015.

2.2.2. Value chain

In South Africa, beef production is characterized by its dual nature with commercialized formal, mature and sophisticated sector on one hand and developing, non-commercial informal sector on the other hand (IDC, 2018) .In the South African beef value chain there are a range of farmers varying from small-scale to commercial operating different management systems, feedlots, abattoirs, wholesalers, retail and consumers. The dualistic nature of South African beef value chain is shown in figure 2.4.

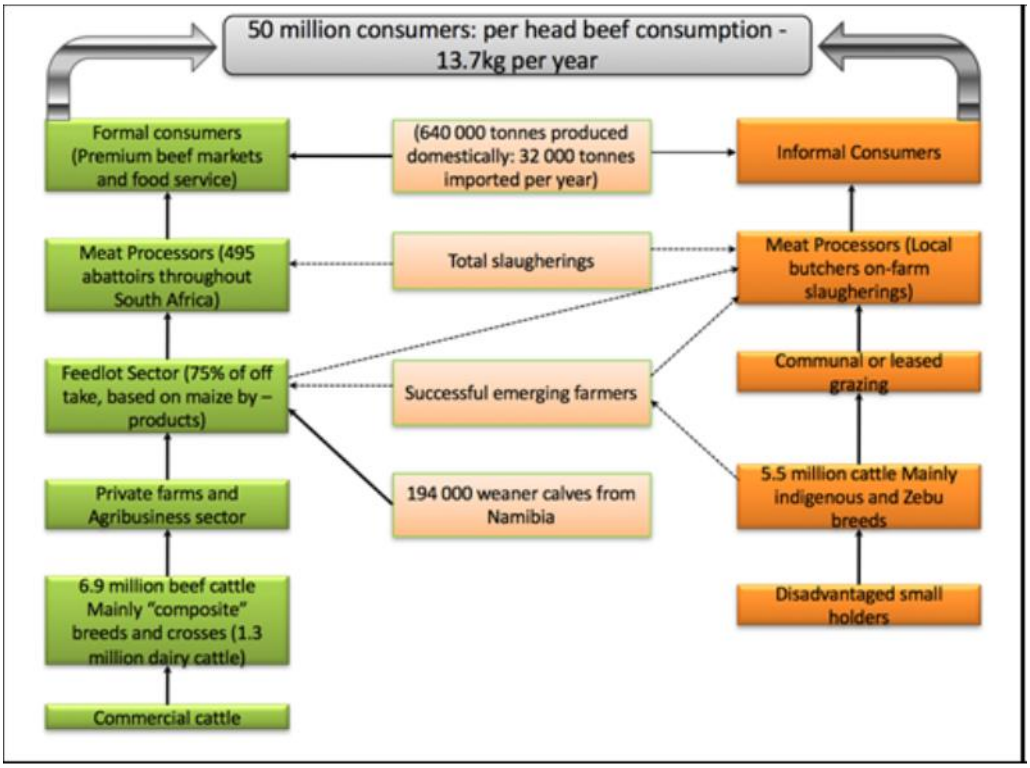

Figure 2.4: Beef Value Chain

Source: IDC, 2018.

Small scale farmers are communal farmers that individually own small numbers of livestock and use communal grazing land that are managed loosely under traditional leadership (Meissner *et al.*, 2013). These farmers bring animals into pens at night and keep them in the kraals made of wood or stones. Livestock are kept for status reasons or as a form of a bank and in some cases as draught absorption power. Cattle are mostly sold when producers need cash and are usually only slaughtered for religious or festive reasons. In this farming group there is little to no herd management practices in terms of the introduction of new genetic materials, calving seasons and health management practices, amongst others (Spies, 2011). Communal farmers contribute very little towards the industry in terms of production. There are approximately 3 million small scale farmers (DAFF, 2017), owning about 5.5 million cattle mainly indigenous and Zebu breed (IDC, 2018).

Emerging farmers are farmers in transition, who were previously excluded from active participation in the farming business and now farm on property that is either leased or purchased with or without government support (Meissner *et al.*, 2013). There are about

240,000 emerging farmers, of which 87,000 have the potential to join the commercial sector (Spies, 2011). Some of these farmers have accumulated wealth from other business sectors or are professionals. Some had livestock in the communal dispensation which they have relocated to their newly acquired farms, others had to purchase their animals. In some cases there are remote or absentee farmers who rely on hired labour for management and spend their time in other businesses, such as taxi owners, lawyers, medical practitioners or any other entrepreneurship that generate sufficient income to acquire or run a farm (Meissner *et al.*, 2013).

Commercial farmers are well-established farmers. Commercial livestock production sector in South Africa is well structured, with farming units ranging from a few hectares with a small number of animals to large farms with thousands of producing animals. The commercial cattle farmers are estimated at 50 000 having 6.3 million beef cattle and 1.3 million dairy cattle (IDC, 2018). Breed variety is high, ranging from indigenous breeds to foreign breeds, to a wide range of crossbreeds as well as breeds specifically adapted for the conditions of South Africa in this category (Spies, 2011). The production is comparatively high, relatively efficient, self-supporting and simulates farming systems in the developed world (Meissner *et al.*, 2013). The commercial beef production is capital intensive with high investment requirement in land, handling facilities, fencing and breeding stock. This also creates relatively high barriers to entry. The majority of cattle producers produce weaner calves that are ready to be marketed at around seven months of age.

A feedlot is a confined area with watering and feeding facilities where livestock are completely hand or mechanically fed to produce consistent quality meat. The animals are well fleshed, lean and have good conformation (Spies, 2011). The commercial sector mostly feed their animals in feedlots. The majority of these cattle producers produce weaner calves that are ready to be marketed at around seven months of age. The majority of cattle, specifically in the case of beef, are marketed through the feedlot industry. Feedlots, usually depend on supply, purchase weaner calves ranging from 160 to 250 kg which are then fed to market weight. Depending on the average daily gain (ADG) and feed conversion ratios (FCRs) cattle are fed for approximately 120 days to an end live weight of 400 - 450 kg (Spies, 2011). Feedlot owners make use of market agents for product (weaner calves) procurement. Small holder farmers sell to emerging farmers, market agents or to the meat processors such as butcheries. Feedlots also import about 194 000 weaner calves from Namibia (IDC, 2018). South African feedlots range from small to large sizes that can accommodate more than 110,000 heads of cattle (Spies, 2011) and feed with grain products such as hominy chop, bran, maize, sorghum, barley, wheat, and silage.

Abattoirs are responsible for slaughtering live animals and produce carcases. The country has 495 abattoirs in slaughtering capacity from as little as two units to more than 1,500 units a day. The abattoir can be divided into abattoirs that are linked to the feedlot sector and the wholesale sector, and those that are mainly owned by farmers and small micro-enterprises. The beef industry produces approximately 640 000 tonnes domestically and import 32 000 tonnes per annum. There are 50 million consumers of beef consuming 13,7 kg per capita (IDC, 2018). Most of the big feedlots own their own abattoirs or are at least to some extent involved in the abattoir sector. Some abattoirs are also integrated vertically downstream in the value chain to wholesale (deboning) level and, in some cases, up to retail level (Spies, 2011)

The value chain players in the beef value chain include feed and feed supplement suppliers, stud breeders and suppliers of vaccinations and preventative medicines, finance suppliers and agents or auctioneers. See figure 2.5.

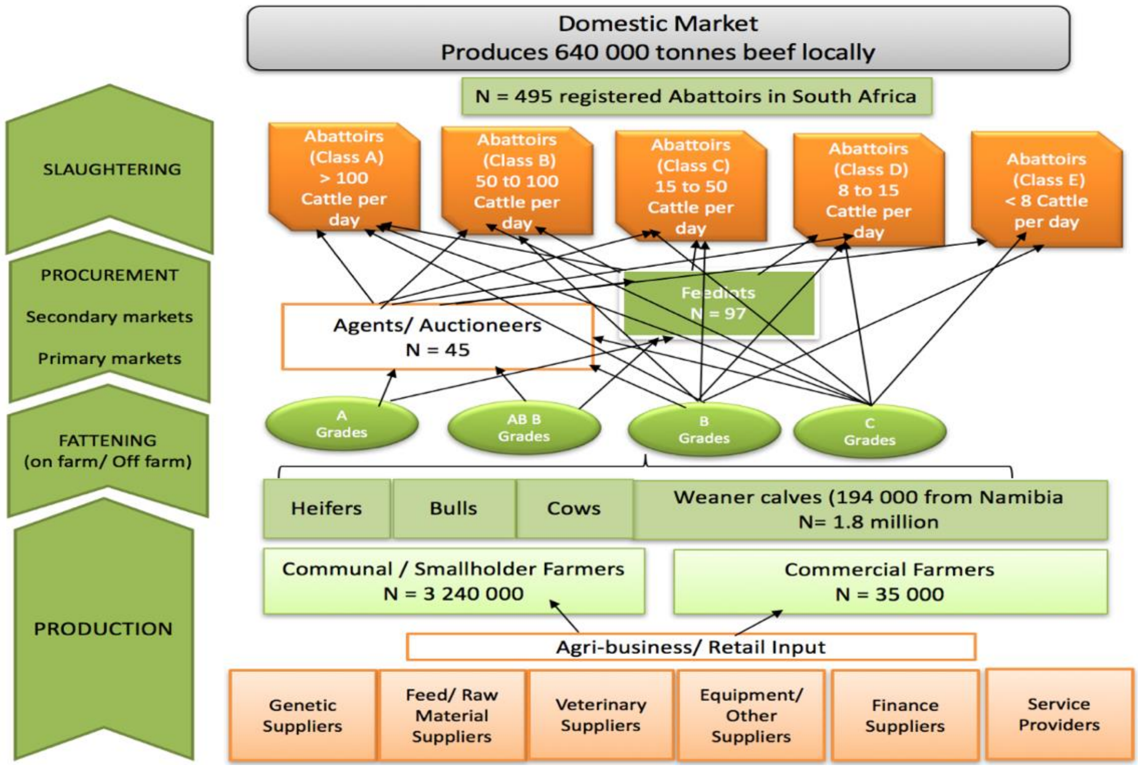

Figure 2.5: Value Chain Players in the Beef Value Chain

Source: IDC, 2018

2.3. Production systems

Different production systems are used to raise and fatten ruminant livestock for food production (Webb and Erasmus, 2013). Livestock farming in South Africa is based on a unique combination and synergy between extensive, mixed and intensive animal production systems. Beef cattle production systems are mainly extensive and based on rangeland or natural pastures (du Toit *et al*., 2013). Beef production systems are classified according to the age at which animals emanating from a production unit are sold. A full description of a system includes the age, mass and carcass class at which animals are marketed, as well as the breeding, management and feeding practices followed. These different production systems are dictated mostly by the availability and type of natural resources, local consumer demand and commercial viability. Animals are reared on either pasture or in feedlots and mostly slaughtered at the young age of about 12 to 16 months before the appearance of permanent incisors, or after development of up to two permanent incisors (Frylinck *et al.*, 2013).

2.3.2. Intensive production system

This system is dominated by commercial farmers producing beef within a feedlot system. Cattle are fed on improved pastures for approximately 120 days in conjunction with high quality protein and mineral supplement to ensure that they realise their full genetic potential for body growth. Once they are adequately grown they are transferred to the feedlot. Most feedlot systems rely on crops grown outside the cattle farm (Subak, 1999 and WWF, 2010). Feeding rations consists of maize grain, lucerne, hay, minerals and fed additives, as well as numerous by products including hominy chop, wheat bran, corn gluten meal, molasses, cottonseed oil cake and palm kernel oil cake. Cattle enter the feedlot at an average weight of 220 kg and grow at an average of 1.5kg per day to an exit market weight of 400 kg to 440 kg (Du Toit *et al.*, 2013). The handling and disposal of animal waste offer significant problems under intensive system and this pose health and environmental risks similar to those of human waste and should be treated accordingly.

2.3.3. Mixed production system

Under this system animals graze on natural and improved pastures. Field crops are cultivated using different tillage system to supplement feed. Industrial fertilisers are used to improve soil fertility. It is practised by emerging and commercial famers, and characterised by medium herd densities and medium productivity. Animals drink at rivers crossing over the farm, dams, boreholes or water troughs. There is no problem of manure management as animals deposit waste in grazing fields improving the veld quality, resulting in less emission from manure management. Most of these farmers are experienced and sell their animals to the abattoirs and feedlots. In most sustainability studies this system has been recommended as sustainable compared to extensive and intensive systems. Weaned cattle are generally sold to feedlots at live weights varying between 160kg and 220kg in order to reduce stocking rates and improve the management of grazing systems. Few farmers retain weaners to the age of 18 months or older on grazing systems with varying amounts of concentrate feeding to produce an acceptable carcass for the South African market (Webb and Erasmus, 2013).

2.3.4. Extensive production system

The extensive beef production system is the main focus of this research project. In extensive beef production system livestock depend primarily on natural vegetation. The main feature of the extensive system is the use of large tracts of land with little or no subdivision, where the animals are able to continuously graze on the natural pasture throughout the year and feed on crop residue after crop harvest (Dick *et al.*, 2014). This is a cost-effective way to keep livestock because they feed on grass and shrubs which grow naturally in the fields and along roadsides instead of grain. The forage production is strongly affected by climatic variations. The grazing areas are often degraded due to low forage availability, and characterized by the presence of bare ground, erosion, and an increasing accumulation of less palatable plants, depending on the diet selection of the animals (Steinfeld, 2004).

The system is practised by commercial small-scale and emerging farmers. Extensive systems are usually found to have higher carbon footprint in terms of kg product than grain-fed systems (Scholtz *et al.*, 2013). This is because milk or meat yields are lower, more numbers are needed to produce the same amount of edible output produced under intensive which translates into more methane emissions for a given quantity of milk or meat (Garnett, 2010). Open topped kraals that are used to keep animals at night by communal farmers occasionally become water lodged during summer rainfall and flooded, thereby rendering the manure prone to nitrogen loss through leaching. During the day animals deposit manure in the veld. The quality of manure is poor due to poor nutrition as farmers do not supplement feeding (Webb, 2013).

2.4. Challenges faced by the beef industry

The global livestock sector is faced with a three-fold challenge. These are similar to the challenges that the South African industry face. The main challenges are (FAO, 2013):

1. The need to increase production to meet demand,
2. To adapt to a changing and increasingly variable economic and natural environment, and
3. To improve the environmental performance of the livestock industry.

All the three challenges are of equally important. This in-turn, implies a reduction in the fodder and water consumption per unit of beef produced and a reduction in the GHG emissions per unit of beef produced. Agriculture is closely tied to climatic conditions. Climate change is transforming the planet's ecosystems (FAO, 2013), threatening the sustainability of livestock production systems by reinforcing existing stressors such as heat stress, droughts, and flooding events which have led to reductions in livestock productivity (Assan, 2014).

2.4.2. Beef production's contribution to climate change

The carbon footprint is used to evaluate the environmental impact of beef production on climate change. Globally, agriculture is said to be a key contributor to climate change, being responsible for about 14% of all GHG emissions. Of this livestock is a key contributor to gas emissions. For livestock production systems, nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) emissions are the three main GHG emitted by the sector and are losses of nitrogen, energy and organic matter that undermine efficiency and productivity (FAO, 2013). Livestock produce GHG's in the form of CH_4 from enteric fermentation, and N_2O and methane from manure management and manure deposited on pastures and veld (rangeland) by grazing animals (Gerbens-Leenes *et al.*, 2013). CH_4 has a global warming potential of 25 times than CO_2, and N_2O has a global warming potential of 298 times than that of CO_2 (IPCC, 2007). Methane is produced in herbivores as a by-product of enteric fermentation and during the storage and treatment of manure, and from manure deposited on pastures.

Du Toit *et al.* (2013), state that cattle are a major source of CH_4 emissions from the livestock sector in South Africa, contributing approximately 72.6% of the total livestock GHG emissions. Eighty per cent of land dedicated to animal production is used for feed production and the production of animal feed can be considered as one of the major hotspots in the environmental impact from livestock production (FAO, 2013). The total amount of greenhouse gas emissions throughout the life cycle of a product is usually expressed from the standpoint of the consumer, as kg of CO_2 equivalent per kg of a product, or from the standpoint of the producer as kg of CO_2 equivalent per unit of area (ha) of the production system (Gerbens-Leenes *et al.*, 2013 and Scholtz *et al.*, 2013). The magnitude of the contribution of transport to overall impacts of animal feed depends on whether the feed is imported or produced at the location (Mogensen *et* *al.*, 2014). A number of researchers in different studies have found that a large percentage of greenhouse gas emission in animal production is related to feed production.

GHG emission from animal feed production come from both the primary stage of crop production and from the use of fossil energy in processing the crop to animal feed and from transporting feed (Mogensen *et al.*, 2014). The main source of this emission is from a process known as enteric fermentation, whereby the microbial decomposition of feed in the rumen of the animal results in the production and release of a substantial quantities of CH_4. Factors that influence enteric methane production in livestock are level of feed intake, diet composition, digestibility and quality of roughage, forage species, C_3 versus C_4 grasses, cultivar of food and variation between animals (Scholtz *et al.*, 2012). Other sources of GHGs associated with beef production include manure handling and land management. These result in CH_4 and N_2O emissions and the production of feed crops, which results in N_2O and carbon dioxide (CO_2) emissions (Desjardins *et al.*, 2014). Carbon dioxide emissions are primarily due to the manufacturing and operation of farm machinery and vehicles, the manufacturing of fertilizers and agrochemicals, as well as the manufacturing of farm buildings and electrical power generation and additional emissions are associated with a change in land management practices.

These changes in cultivation practice can influence carbon stored in the soil, resulting in either CO_2 emissions or CO_2 sequestration, as soil organic carbon (Desjardins *et al.*, 2014). Du Toit *et al*. (2013) found that the extensive beef cattle sector is the largest contributor to the cattle sector's GHG emissions, contributing 54.7% and 28.6% for commercial and emerging/communal cattle, respectively. The Eastern Cape and Kwazulu-Natal have the highest beef cattle methane emissions in both commercial and emerging/communal production. This is because of the cattle population size in the areas. According to Garnett (2010) in the case of ruminants, extensive systems are usually found to have a lower per-area footprint than intensive grain-fed systems, but a higher footprint if expressed in terms of kg/product. Biodiversity losses, and land degradation in the form of deforestation and overgrazing are often linked to livestock production activities (Steinfeld, 2004). FAO (2013) state that higher emissions are largely caused by low feed digestibility leading to higher enteric and manure emissions, poorer animal husbandry and lower slaughter weights leading to slow growth rates and to more emissions per kg of meat produced, and higher age at slaughter as longer life leads to more emissions.

2.4.3. Climate change influence on livestock production

Worldwide, beef cattle are generally reared outdoors with consequent exposure to natural conditions and are only maintained in housing systems to a limited extent. Beef cattle are particularly vulnerable not only to extreme environmental conditions, but also rapid changes in these conditions (Nardone *et al*., 2010). Climate change also has direct and indirect impacts on livestock production (Taqi *et al*., 2013). The direct effects include the interchange of heat between the animal and its environment, associated with air temperature, humidity, wind speed and thermal radiation (Oyhantçabal *et al*., 2010). Most direct effects are revealed on animal health, heat stress, well-being and production (Taqi *et al*., 2013). As pests and diseases move into new areas, the poor are more likely to experience increased mortality among their animals and also the first to suffer market impacts of climate change on the cost of inputs (Mandleni, 2011).

The indirect effects include the influence of climate on the quantity and quality of fodder crops and grains, and the severity and distribution of diseases and parasites (Oyhantçabal *et al*., 2010). Due to climatic induced factors the vegetation dynamics has changed, affecting the grazing capacity. Temperature increases and rainfall decreases has affected the grasses and legume species on rangelands, promoting especially unpalatable plant species and reducing livestock productivity (Assan, 2014). High temperatures may compromise reproductive efficiency of farm animals for both sexes and hence negatively affect milk, meat and egg production (Nardone *et al.*, 2010). Ruminant grazing intensity in rangelands and extensive grasslands is projected to further increase (Thornton, 2010).

This could result in intensification of livestock production in the humid and sub-humid grazing systems of the world. Intensification is likely to be constrained by increased droughts and heat waves in some arid and semi-arid regions (Soussana and Lemairec, 2014). Changing climatic patterns are increasing desertification in some areas, resulting in a decline in rangeland resources which are often insufficient to meet current demand, coupled with a fall in total feed resources due to overgrazing. This is often the case with dry environments which result in nutrient shortages for livestock (Mandleni, 2011). The higher predicted temperatures may result in heat stress in livestock during certain times of the day that may not be accommodated by behavioural adaptation, resulting in lower productivity (Turpie and Visser, 2013).

Climate change can have an effect on land use and land use systems. These land-use changes can cause a different composition in animal feed intake and a change in the ability of smallholders to manage feed deficits in the dry season. Negative effects on animal productivity and on the maintenance of livestock assets can subsequently be experienced (Mandleni, 2011). The continuous increase in temperature is predicted to have a direct effect on;

- water supplies,
- the future distribution of livestock species and breeds,
- their adaptability to increased heat load, incidence and type of diseases,
- feed supplies,
- grazing potential, and
- food (nutrition) security (Scholtz *et al.,* 2013).

According to Nardone *et al.* (2010) livestock systems based on grazing and the mixed farming systems will be more affected by global warming than an industrialized system. This is due to the negative effect of lower rainfall and more droughts on crops and on pasture growth, and the direct effects of high temperature and solar radiation on animals. The productivity of pastures depends on rainfall. More irregular rainfall distribution, with more frequent droughts, will mean that livestock will suffer more periods of fodder shortages, particularly in areas with shallow soils (Oyhantçabal *et al*., 2010).

2.4.4. Impact of climate change on water resources

South Africa is a water scarce country with a highly variable climate which is likely to be significantly exacerbated by the expected effects of climate change. Some countries in Southern Africa are already experiencing considerable water stress as a result of insufficient and unreliable rainfall that changes rainfall patterns or causes flooding (Assan, 2014). Agriculture is also the largest consumer of fresh water and is vulnerable to changes in water availability, increased water pollution and soil erosion from more intense rainfall events and increased evapotranspiration. The livestock sector increasingly competes for scarce resources such as land, water, and energy, and has a severe impact on air, water and soil quality, because of its emissions (De Vries and De Boer, 2010). Animal products have a particularly large water requirement per unit of nutritional energy compared to food of plant origin (Gerbens-Leenes *et al.,* 2013). The South African government is faced with the challenge of feeding and empowering a large segment of its people most who live in rural areas and practice dry land agriculture (Kahinda and Taigbenu, 2011).

Water availability is a key climate change-related vulnerability and negative impacts on the availability of water will be felt by people, ecosystems and the economy (Hooda *et al.*, 2000). Groundwater and surface water is expected to decrease, and increased evaporation could increase soil salinity, thereby limiting plant growth (Assan, 2014). Land management on farms has a major impact on water availability and quality (WWF, 2010). Increasing heat stress will significantly increase water requirements for livestock, resulting in overgrazing near water points causing land degradation and endanger biodiversity (Assan, 2014). Soil from eroded areas, for example, flows into rivers changing their flow and reducing the storage capacity of dams. Poorly applied fertilizers run off into rivers, polluting water sources and causing algal blooms. Pesticides from poorly managed farms are also a major source of water pollution, with negative effects on the health and well-being of people and the environment (WWF, 2010).

Water which include rivers, dams/ponds, bore-holes, wells and springs dry up during the dry season due to evaporation caused by extreme temperatures. Livestock production in such cases face a number of challenges associated with watering animals, resulting in animals herded for long distances (Assan, 2014). There are sufficient water resources globally to produce food over the next 50 years. That is if water use for agriculture is better managed. Local and regional scales water scarcity is expected to constrain efforts to increase agricultural production (De Fraiture and Wichelns, 2010). Livestock production is an important livelihood strategy for smallholder farmers in Africa and a major consumer of water. Changes in water quantity and quality due to climate change, apart from affecting water sources for livestock, are expected to reduce the pasture species biodiversity of rangeland. This could increase the vulnerability of livestock production which is predominantly grassland based (Assan, 2014).

2.4.5. Mitigation and adaptation to climate change

There are options for reducing absolute emissions and there are major opportunities for sequestering carbon in the soil using carbon sinks in degraded pastures. These also generate benefits in terms of restoring natural fertility, increasing productivity and reducing erosion (Oyhantçabal *et al*., 2010). Livestock farmers have to mitigate emissions and adapt to change. The adaptation and mitigation that are necessary may require significant changes in production technology and livestock production systems. This could affect productivity, incomes and livelihoods (Thornton *et al*., 2013). According to Mandleni (2011), adaptation option is a better way so far in order to deal with climate change than mitigation in developing countries and adaptation measures should help communities deal with climate change. Mandleni (2011) defines adaptation to climate change as the adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Scholtz (undated) define adaptability of an animal as the ability to survive and reproduce within a defined environment or the degree to which an organism, population or species can remain or become adapted to a wide range of environments. Thornton *et al.* (2013) states that livestock production systems are highly heterogeneous and different production systems have different capacities to adapt or to take on board the policy and regulatory changes that may be required in the future. Adaptation indicators include;

- Reproductive traits such as fertility, survival, birth rate and peri-natal mortality;
- Production traits such as growth rate, milk production, low mortality and longevity; and
- Health traits such as faecal egg counts and number of external parasites (Scholtz, undated).

Developed and developing countries differ in their adaptation capacity and the expected interactions between climate change adaptation and mitigation. Developing countries that have a low adaptation capacity will have to apply a closer relationship between climate change adaptation and development policy (Mandleni, 2011).

Mitigating the animal agriculture sector's contributions to climate change necessitates comprehensive and immediate action by policy makers, producers, and consumers. Enhanced regulation is required in order to hold facilities accountable for their GHG emissions (FAO, 2013). Most agricultural programmes and information are initiated at high levels in government for regional implementation and are not always adapted to local conditions (DEA, 2013). Goodland and Anhang (2009) believe that recommending change directly to industry will be more effective than recommending policy changes to governments, which may or may not eventually lead to change in industry. For both commercial and small scale farmers, adaptation will require an integrated approach that addresses multiple stressors, and will have to combine the indigenous knowledge/ experiences of vulnerable groups with the latest specialist insights from the scientific community (DEA, 2013). Promoting adapted pasture varieties will play a major role in reducing vulnerability of feed resources to climate change (Assan, 2014).

This improves preparedness for harsh climate induced conditions on livestock production itself and raise survival rates and livestock performance due to the availability of feed resources (Assan, 2014). Improving the digestibility of the diet, through feed processing or addition of locally available improved forages, results in enhanced lactation performance and reduced CH_4 emissions (FAO, 2013). Introduction of adapted pasture species will mitigate the effects of climate change as these should have wide spread adaptation to environmental stresses, ease of management and acceptability by livestock farmers (Assan, 2014). Diet improvement through improved digestibility has the highest mitigation potential, owing to its large impact on several sources of emissions (FAO, 2013). Goodland and Anhang (2009) also suggest that livestock-related GHGs could be managed by governments through the imposition of carbon taxes in which case leaders in the food industry and investors would search for opportunities that such carbon taxes would help create.

Mitigation largely results from a reduction in animal numbers, yield gains allow constant milk production to be achieved with 10% fewer animals (FAO, 2013). Livestock health policies should take into account the need to adapt to a changing climate, as well as the potential for near-term benefits to livestock health from a range of policies to mitigate climate change (Assan, 2014). Descheemaeker *et al.* (2010) states that, with increasing demand for animal products along with an increase in global water scarcity and competition for water, there is a pressing need to increase livestock production without depleting more water while safe guarding the environment. Controlling use of water as a means of slowing the effects of climate change and sustain livestock production should be a priority. Wetland protection may be one of the strategies to ease on water shortage in some parts of the region, especially the semi-arid areas (Assan, 2014). The efficiency of water utilization is another primary mission necessary to achieve sustainability of animal agriculture in expectation of increasing water scarcity and worsening quality.

Beef cattle producers can adapt to climate change and reduce GHG emission by;

- Improving production efficiency,
- Breeding programmes to reduce the carbon footprint of livestock products,
- Implementing new or adapted climate smart production systems, and
- Using of appropriate or adapted genotypes (Scholtz *et al.*, 2013).

In developing countries, livestock production efficiency for small-scale farmers and pastoralists is limited by factors such as shortage of livestock feeds, poor health for human and livestock, poor access to markets, unresponsive policy environments, and degradation of natural resources (Mandleni, 2011). Sustainable agriculture is recommended in the literature as the best possible option to adapt and mitigate climate change challenges while improving productivity. Adaptation options for the South African agriculture sector presented in the DAFF Climate Change Adaptation and Mitigation Plan include conservation agriculture, climate smart agriculture, ecosystem-based adaptation, community-based adaptation and agro ecology, sustainable water use and management; and sustainable farming systems (DAFF, 2015).

Conservation agriculture (CA) aims to make better use of agricultural resources through the integrated management of available soil, water and biological resources, combined with limited external inputs. In mixed farming systems where livestock farmers also produce crops, minimum tillage should become the norm rather than the exception. Minimum tillage ensures higher organic matter soil content which leads to better moisture retention (RPO and NERPO, 2014). Climate smart agriculture entails the integration of land suitability, land use planning, agriculture and forestry to ensure that synergies are properly captured and that these synergies will enhance resilience, adaptive capacity and mitigation potential (DAFF, 2015). It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges (DEA, 2013). Ecosystem-based adaptation includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change.

There are several existing ecosystem based adaptation related projects in South Africa. These include sustainable management and/ or restoration of upland wetlands and floodplains for maintaining water flow and quality; conservation and restoration of forests to stabilise slopes and regulate water flows; and establishing wind-breaks to increase resilience of rangelands (DEA, 2013). Community Based Adaptation provides information and concrete examples of potential climate change impacts and adaptation measures that are location specific and community managed. It also provides information that can be shared and replicated in an appropriate format and manner acceptable to communities (DEA, 2013). Community-based adaptation works to empower people to plan for, and cope with, climate change impacts by focusing on community led processes grounded in the priorities, needs, knowledge and capacities of communities. Agro-ecology approaches include:

- recycling nutrients and energy on the farm, rather than introducing external inputs;
- integrating crop and livestock management practices;
- diversifying species and genetic resources in agro-ecosystems over time and space and
- focusing on interactions between production components and productivity across the agricultural system (DEA, 2013).

Sustainable water use enhance water availability through adaptation options that consider sustainable water use and management as a key strategy for increasing agricultural productivity and securing food security in South Africa (DEA, 2013).

2.5. Sustainability of beef production

The sustainability of livestock farming systems has become an important issue for public and scientific debate (Bernués *et al*., 2011). This is especially in relation to global concerns about climate change, population growth and the quality of the agro-ecosystem services that are provided to society and their trade-offs. Tilman *et al*. (2002) define sustainable agriculture as practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered. The Global Round Table For Sustainable Beef Production (2014) define sustainable beef as a socially responsible, environmentally sound and economically viable product that prioritizes planet, people, animals and progress.

Environmentally sound beef production include maintenance of good biological and physical soil health, good management of grasslands and pastures to avoid over grazing, minimization of water use and pollution, minimization of air pollution, reduction in GHG emission per unit of output, responsible land use and maintenance of biological biodiversity. Each farm represents a unique combination of biological, climatic, soil and management conditions. There is no single way to secure sustainability, livestock production systems differ widely in terms of the use of resources, degree of intensification, species and orientation of production, local/regional socio-economic and market context and cultural roles (SAI Platform working group, 2013).

2.5.2. Previous studies on beef production related to environmental sustainability

There has been a large number of studies considering the impacts of livestock on environmental demand. A selection of those has been listed in Table 2.1.

Table 2.1: A Literature Review of Studies Considering Environmental Demand for Livestock

Author		Methodology	Study	Aim	Emission factors
Picasso *et al*., 2014		LCA methodology was used to study some of the environmental impacts of the beef production systems, including farm activities and the production of farm inputs. Methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2) were accounted in calculating GHG emissions based on Intergovernmental Panel on Climate Change (IPCC) equations	Sustainability of meat production beyond carbon footprint: a synthesis of case studies from grazing systems in Uruguay	The objectives of this paper were to quantify carbon footprint using various metrics and several other environmental variables: fossil energy consumption, soil erosion, nutrient balance, pesticide ecotoxicity, and impact on biodiversity, among fifteen beef grazing systems in Uruguay	Beef systems with grazing finishing have greater GHG emissions than feedlot finishing
Meissner *et al*., 2013		Life Cycle Assessment (LCA)	Sustainability of the South African Livestock Sector towards 2050. Part 2: Challenges, changes	in-depth self-assessment of the challenges facing the	The socio-economic contribution and growth of the livestock sector are satisfactory, in fact increasing as a

			and required implementations.	sector and how these should be responded to	proportion of total agriculture, and are not over-compromising resources and the environment
du Toit *et al.*, 2013		Tier two methodology of the Intergovernmental Panel on Climate Change (IPCC)	Direct methane and nitrous oxide emissions of South African dairy and beef cattle	to estimate direct methane and nitrous oxide emissions of South African dairy and beef cattle in total and per province	Beef cattle in extensive systems were the largest contributor (83.3%), followed by dairy cattle (13.5%), and feedlot cattle (3.2%).
Dick *et al.*, 2014		Life cycle assessment (LCA) has been used. The analysis involves different levels of organization, which are limited to environmental aspects, and does not consider social and economic issues. GHG emission were calculated according to the IPCC (2006b), tier two methodology	Life cycle assessment of beef cattle production in two typical grassland systems of southern Brazil	To analyse the main environmental impacts of two typical beef cattle production systems from southern Brazil: the extensive system (ES) and the improved system (IS). Additionally, it identifies the components and processes that have the greatest environmental Impact in terms of (a) global warming, (b) land use, (c) freshwater depletion, (d) metal depletion; (d) fossil depletion, (e) terrestrial	The GHG emissions/kg LWG in the IS was found to be 40.67% of the emissions obtained in ES. In the ES, the fresh water depletion was 0.217 m^3/kg LWG. In the IS, the freshwater depletion was 0.0949 m3/kg LWG. The difference between the two systems is due to the lower quality of the forage consumed by the animals in the ES compared with the IS and is based on the differences in dry matter (DM)

				acidification and (f) freshwater eutrophication	intake/animal/day, the digestibility, and the pasture use efficiency related to the time required to produce one kilogram live weight gain (LWG).
Subak, 1999		Greenhouse gas emissions from two livestock production systems at opposite ends of the spectrum as regards energy inputs, are assessed according to a range of indicators—biophysical capital loss, topsoil loss, and greenhouse gas emissions.	Global environmental costs of beef production	To evaluate the impact on greenhouse gas emissions of beef produced under different management systems and compares these results with the estimated biophysical capital alteration of these same systems	The results indicate that methane emissions from the pastoralist system are nearly twice that of the feedlot system. When energy is included feedlot system has a higher GHG emission. The \$/kg CO_2 equivalence value estimated in this paper provides a social cost estimate that has an upper limit of about nine percent of the current market value of beef and a central value of 3–5%.

All of these studies in Table 2.1 estimated that the extensive system has a higher GHG emission than intensive systems. Dick *et al*. (2014) found that water use in intensive system is higher than in extensive system. This water value is mainly attributed to the relatively large consumption by the animals because 4.35 days are required to produce one kilogram of live weight in extensive system which is more days than in the intensive systems. The GHG emission difference between the two systems is due to the lower quality of the forage consumed by the animals in the extensive system compared with the intensive and is based on the differences in dry matter (DM) intake/animal/day, the digestibility, and the pasture use efficiency related to the time required to produce one kilogram LWG (Dick *et al*., 2014), and expend more energy over a larger range (Subak, 1999).

Subak (1999), compared US feedlot and African pastoral system and found higher methane emissions in extensive compared to feedlot system. However, when carbon dioxide embodied in fuel is considered as well, higher emissions are found in the feedlot system. This is because the African cattle have a higher methane conversion rate from lower quality feed, live longer than feedlot animals, expend more energy eating over a larger range, and produce less meat. These factors compensate for the fact that the animals are eating less than the feedlot animals (Subak, 1999). A social cost with an upper limit of nine percent of market value of beef and a central value of 3-5% was used by Subak (1999) in allocating monetary values to GHG emission. Subak (1999) estimated 14.9kg of GHG emission in feedlot system and 8.1 kg pastoral system. The methane emissions before the inclusion of energy are 3.6 kg and 6.6 kg in intensive and pastoral system, respectively. Estimated climate change costs were estimated to be between 0.03$/kg to 0.14$/kg in intensive and 0.07$/kg to 0.04$/kg in pastoral system.

This study differ from the studies listed in Table 2.1 by assessing environmental demand and benefits of different beef production system and different categories of farmers in monetary values. Extensive beef production has been found to have higher GHG than other production system in most of the studies; however this system include commercial and small farmers using different management practises. This study will separate extensive production system based on categories of farmers. Environmental costs will be expressed in monetary values and profitability will be calculated to determine the environmental sustainability of each production system and in each category of farmers. Production efficiency of different production systems and farmers will also be calculated to determine the farmers and production system that is able to use resources efficiently with lower GHG emissions. Suggested farming methods to improve environmental sustainability will also be identified.

2.6. Conclusion

The global demand for food is rapidly growing. Currently the country does not meet the local demand for beef and there is an increasing pressure to export to other countries. Livestock products contributes 27% of the consumer food basket on a weight basis. Efforts to increase productivity in order to supply local demand of animal products need to be made in all the production systems. In South Africa beef production systems are mainly extensive and based on natural pastures or rangeland. Besides the global increase on the demand of meat products, the livestock industry is also facing the challenge of adapting to climate change and improving the industry's environmental performance. Agriculture is closely tied to climatic conditions. Carbon foot print is used in evaluating the environmental impact of beef production on climate change. Livestock production is said to be the key contributor on climate change in the agricultural sector. Extensive beef production as the largest contributor to climate change in the cattle industry. Climate change has direct and indirect impacts on animal production. These effects include the quantity and the quality of fodder crops, decline in rangeland resources, decrease in water supply, etc. agriculture is the largest consumer of water and is vulnerable to changes in water availability.

Sustainable agriculture is recommended as the best possible option to adapt and mitigate climate change challenges while improving productivity. Sustainable agriculture mostly defined as practices that meet current and future societal needs by maximizing the net benefit to society when all costs and benefits of the practices are considered. Sustainability in agricultural systems incorporates concepts of both resilience and persistence, and addresses many wider economic, social and environmental outcomes. SAI Platform Beef Working Group identified economic, environmental and social principles for sustainable beef farming. Extensive beef production has been found to have higher GHG than other production system in most of the studies. This study will assess the environmental demand of extensive beef production on different category of farmers. Environmental costs will be expressed in monetary values and profitability will be calculated to determine the environmental sustainability of each production system and category of farmer's profile. The typical farm profiles will be developed and environmental sustainability assessment will be done using cost benefit analysis method.

3. MATERIALS AND METHODS

3.1. Introduction

The main aim of this project is to assess the impact of extensive beef production systems on the environment in terms of costs to the environment. In Chapter two the impact of beef production was shown to be most severe in terms of emissions and water consumption. To determine the impact in a financial format requires a measurement that can accurately capture the financial gains as well as the costs to the environment. For this purpose cost benefit analysis is used to assess environmental sustainability of extensive beef production by small scale as well as commercial farmers.

This chapter introduces cost benefit analysis (CBA) as a tool for measuring impact of a farming activity on the natural environment. The cost benefit analysis is also explained in terms of the mechanism and the process of determining costs and benefits. The general purpose and development of the method is introduced to underpin the value of it where resources are concerned. It also introduce the concept of financial analysis of the farm which serves as measuring tool for the financial profitability of beef farming in extensive environments. The typical farm concept as a platform for comparing various farm systems is introduced and the chapter finish with a description of how the research methods are practically employed.

3.2. Cost Benefit Analysis

The CBA involves the definition of scenarios of desired changes, the establishment of baselines against which changes are to be measured, estimation of physical impacts, valuation of these impacts, and estimation of the costs of achieving the desired changes (Panayotou, 1997). A cost-benefit analysis is defined by Belli *et al*. (1997) as a systematic process for calculating and comparing benefits and costs of a project. It provides a useful basis for decision-making and assists in the systematic appraisal and management of capital and current projects (CEEU, undated).

3.2.1. Background of Cost Benefit Analysis

CBA was originally conceived to apply to projects undertaken by the public sector (Campbell and Brown, 2003). The actual technique of cost benefit analysis was devised in the 1930s and was first applied in the USA for large water development projects. Since then, the technique has been used in many other fields to indicate whether benefits of undertaking a given activity exceed their costs (Bizoza and De Graaff, 2012). Cost Benefit Analysis is concerned with economic choice and endeavours to assist decision makers in making choices concerning scarce resources (CEEU, undated). Cost-benefit analysis provides a robust method for evaluating the costs and benefits (including both market and non-market impacts) of a project or policy change in current monetary value to society as a whole. The power of CBA as an analytical tool rests in in the fact that the costs and benefits are expressed as far as possible in monetary terms and hence are directly comparable with one another. The values are determined in terms of the claims they make on and the gains they provide to the community as a whole (Bizoza and De Graaff, 2012). In the private sector, the goal of the organisation is to maximise profits and its investment decisions is only concerned with private costs and benefits which are decided by the market mechanism, and in the public sector the goal is to allocate the available scarce resources efficiently to improve the welfare of the society (CEEU, undated).

One of the purposes of CBA is to help social decision making and to facilitate more efficient allocation of resources (Panayotou, 1997). Any allocative decision involves making choices between alternative approaches to achieve a specific policy objective and rank priorities (CEEU, undated). Resources are allocated efficiently when the benefit an individual derives from the last unit of consumption is just equal to the cost of production of that unit (Bizoza and De Graaff, 2012). The decision maker, before making a decision to invest, need clarity on whether the proposed project is;

- efficient from a private market perspective,
- attractive from the viewpoint of the firm’s shareholders,
- contributes to economic efficiency in the sense that it improves the allocation of scarce resources, and
- is worthwhile from the viewpoint of the group of people the decision maker represents (Campbell and Brown, 2003).

CBA involves the identifying and valuing of costs and benefits of the project; analysis of financial aspects, economic aspects and risk and uncertainty of the project. Net present value (NPV), cost benefit ratios and internal rate of return (IRR) are commonly used as decision criteria for determining profitability and feasibility of the activity at project level and at the national level (Gittinger, 1982).

3.2.2. Financial Analysis

A financial analysis must be included in the CBA to compute the project's financial performance indicators (European Commission, 2014). A financial CBA is made from the perspective of a person, group or unit directly involved in the project, a farm, for example. Only expenses that will be made by the farm and benefits that will accrue to the farm are taken into account in a financial analysis (Howlett and Nagu, undated). The financial analysis is carried out in order to:

- assess the consolidated project profitability;
- assess the project profitability for the project owner and some key stakeholders;
- verify the project financial sustainability, a key feasibility condition for any type of project; and
- outline the cash flows which underpin the calculation of the socio-economic costs and benefits (European Commission, 2014).

This makes a financial CBA much simpler to calculate because it is more demarcated. Financial analysis is concerned with the private profitability and is based on the financial flows which relate to market prices for products and inputs, the terms of credit and borrowing, tax and subsidy policy, financial depreciation and other financial conventions (Howlett and Nagu, undated). It identifies the project's net cash flows to the implementing entity and assesses the entity's ability to meet its financial obligations and to finance future investments (Belli *et al.*, 1997). The only practical way to compare differing goods and services is to allocate to each a monetary value. It is conventional practice to use prevailing, market input and output prices in the financial evaluation (FAO, 1995). A standard rule for determining market prices for agricultural commodities produced in the project is to seek the price point of sale of a relatively competitive market to estimates the product value in economic and financial terms (Gittinger, 1982).

This is usually the farm gate price. In a market that is not relative competitive the prices will have to be adjusted to reflect the value of the commodity. In the case of internationally traded commodities such as fertilizer, grains, oilseeds or timber, prices are usually derived from forecasts prepared periodically by the World Bank (FAO, 1995). The most important objective of financial analysis is to assess the financial effects of the project to farmers, public and private firms, government operating agencies and others who may be participating in the project (Gittinger, 1982). Detailed financial projections are needed to complete this analysis. Other objectives include judgement on efficient resource allocation, assessment of incentives, provision of sound financial plan, coordination of financial contributions and assessment of financial management competence.

3.2.3. Economic analysis

Economic cost-benefit analysis is an important component of applied welfare economics; a branch of economic science which has steadily evolved over more than 200 years (Jenkins *et al*., 2011). The economic analysis appraises the project's contribution to the economic welfare of the region or country (Belli *et al*., 1997). It is made on behalf of the whole society instead of just the owners of the infrastructure, as in the financial analysis (European commission, 2008). In economic analysis all costs and benefits are taken into account, including externalities. Even if a project entity does not pay for the use of a resource it does not imply that the resource is a "free good". If a project diverts resources from other activities that produce goods or services, the value of what is given up represents an opportunity cost of the project to society (Belli *et al.*, 1997). The financial prices are adjusted to reflect the value to the society as a whole of both inputs and outputs of the project (Henley and Splash, 1993). The new values are referred to as shadow prices. Shadow prices represent the social opportunity cost, instead of observed distorted prices.

Observed prices of inputs and outputs may not reflect their social value because in some markets it includes a mark-up over marginal costs; trade barriers, where the consumer pays more than he/she could elsewhere. Howlett and Nagu (undated) state that shadow prices are often applied using conversion factors (CF) or adjustment factors (AF), which are defined as follows:

AF = (Shadow price/market price) -1 x 100%

CF = shadow price/market price

In other cases, there may be project costs and benefits for which market values are not available. For example, there might be impacts, such as environmental, social or health effects, without a market price but which are still significant in achieving the project's objective and thus need to be evaluated and included in the project appraisal. When market values are not available, effects can be monetised.

For non-traded goods, such as farm labour, locally-made raw materials or many fruits and vegetables, the aim is to set prices which reflect their opportunity costs (FAO, 1995). A distinction between traded and non-traded goods must be made, and a decision must be taken as to whether to compensate for distortions in the pricing of foreign exchange through the use of a shadow exchange rate or through the application of conversion factors to the price of non-traded goods (Gettinger, 1882). With the correct analysis, the final result should be the same (FAO, 1995).

When adjusting financial values to economic values, Gettinger (1982) divides necessary adjustments into three steps, namely:

- The first step is the adjustment for direct transfer payments.
- The second step is the adjustments for market price distortions in traded items. The boarder price is adjusted to allow for domestic transport and marketing costs between the point of import or export and the project site. This results in the efficiency price to be used in the project account. Boarder price is defined as the opportunity cost of traded goods (Howlett and Nagu, undated). If the conversion factors to allow for foreign exchange premium are used, the economic value of traded item would be obtained by converting the foreign exchange price to its domestic currency equivalent using official exchange rate. If the shadow exchange rate is used to allow for the foreign exchange premium, the economic value of a traded item would be obtained by converting the

foreign exchange price to its domestic currency equivalent using the shadow exchange rate (FAO, 1995).

- The third step is the adjustment for distortions in market prices of non-traded item.

If a shadow exchange rate approach is used to allow for the foreign exchange premium, and if the market price for non-traded item is a good estimate of the opportunity cost, or willingness to pay is the criterion, market price is accepted as economic value. If a conversion factor approach is used to allow for foreign exchange premium, all prices for non-trades items are reduced by multiplying them by the appropriate conversion factor. When willingness to pay is the criterion or market price considered to be the good estimate of opportunity cost the market price is accepted as a basis for evaluation and then reduced by multiplying it by conversion factor to obtain the economic value. To estimate the contribution a project make to the national income financial farm budgets, accounts of processing industries and budget of government agencies have to be changed from financial prices to economic values. Then the values must be aggregated to reach the economic incremental net benefit of the project. This is generally called economic cash flow (Gittinger, 1982).

3.2.4. Identifying Costs

Costs can be described as the intended or unintended negative effects of a project. Benefits can be described as the intended or unintended positive effects of a project. These benefits and costs are of different types as domains of application vary considerably (Bizoza and De Graaff, 2012). Some of the items that are included in the financial costs of a project are not included in economic costs, as they do not increase or decrease the availability of real resources to the rest of the economy (Desai, 1997). When examining costs the decision maker has to determine whether the item reduces the net benefit or the net income of a firm (Gittinger, 1982). In financial cost benefit analysis the interest is on the items that entail direct monetary outlays and in economic analysis the interest is in the opportunity costs for the country (Belli *et al*., 1997). All costs must be identified for each option, including the purchase of capital assets or use of existing assets and running costs (Snowdon and Harou, 2013). One approach in identifying costs involves the distinction between fixed and variable costs. Cost can also be categorised as direct, indirect or attributable overheads. When attributable overheads are included, these should be calculated on an incremental basis only i.e. the change in overhead costs resulting from the project (CEEU, undated). Costs should also be expressed in terms of opportunity costs (Snowdon and Harou, 2013).

3.2.4.1 *Working Capital*

Desai (1997) defined working capital in financial analysis as net current assets consisting of inventories, including goods in process, net receivables, marketable securities, bank balance and cash in hand. In order to carry out an economic activity, a certain amount of investment has to be made in items that facilitate the conduct of transactions, and these items include cash, accounts receivable, accounts payable, prepaid expenses, and inventories (Jenkins *et al*., 2011). In economic analysis only inventories that constitute real claims on the nation's resources should be included on the project economic costs. Other items of working capital reflect loan receipt and repayment flows are not included in the economic analysis (Desai, 1997).

3.2.4.2 Contingency allowance

Allowance should be made where contingencies are part of the expected costs of the proposal and included in the CBA (CEEU, undated). Contingency allowances may be divided into those that provide for physical contingencies and those for price contingencies (Gittinger, 1982). Physical contingencies represent monetary value of additional real resources that may be required beyond the base cost to complete the project (Desai, 1997). Price contingency allowances comprise two categories, those for relative changes in price and those for general inflation (Gittinger, 1982). When estimating project costs for financial planning purposes, both physical and price contingencies are included, but in economic cost general price contingencies should be excluded and economic benefits are measured in constant prices (Desai, 1997).

3.2.4.3 Sunk costs

Sunk costs are costs incurred in the past in connection with the proposed project (Belli *et al*., 1997). These are costs incurred irrespective of whether the project proceeds or not. Such costs should not be included in the project costs, provided their use in the project involves no opportunity cost. An example is the cost of a project environmental impact assessment (EIA). When deciding whether continuing with a project is feasible or not, the cost of the EIA (which was incurred in the past) is irrelevant (Department of Environmental Affairs and Tourism, 2004). Another example would be a project requiring the use of facilities that already exist.

3.2.4.4 Transfer of payments

Some entries in financial accounts really represent shifts in claims to goods and services from one entity in the society to another and do not reflect changes in national income (Gittinger, 1982). The items that do not increase or decrease the availability of real resources to the rest of the economy, but affect the distribution of financial costs and the benefits between project entity and other entities, and among project beneficiaries are referred to as transfer of payments (Desai, 1997). In agricultural project analysis four kinds of direct transfer payments that are common include; taxes, subsidies, loans, and debt service (Gittinger, 1982).

In general, transfer payments should be excluded to economic analysis because from society's perspective such payments have no effect on real resources and benefits are merely transferred from one part of society to another (CEEU, undated). They can affect the income of government, and that of a tax payer and recipient simultaneously and in opposite and identical amount, thus cancelling out in the summation of economic analysis (Desai, 1997). However, the economic cost of an input should include the tax or subsidy element if the demand is non-incremental. If government is correcting an externality by applying tax or subsidy to increase or decrease production, the economic cost of the input should also include the tax or subsidy element (Desai, 1997). In financial analysis these are included as costs where they decrease output and as benefit when they increase output (Gittinger, 1982).

3.2.4.5 Depreciation Costs

The financial accounts of agencies implementing a project include the provision for depreciation and amortization on the basis of prevailing accounting practice. For economic analysis the stream of real investment required to realise and maintain project benefits is included in the resource flow, together with residual value of these assets at the time they are released from project use at the end of the project's life (Desai, 1997).

3.2.4.6 Externality Costs

Projects can lead to benefits created or costs incurred outside the project itself (Gittinger, 1982). The externalities are real, and genuinely impose costs or benefits on the well-being of people within a country (Jenkins *et al*., 2011). Economic analysis must take account of these external costs and benefits so they can be properly attributed to the project investment (Gittinger, 1982)

3.2.5. Identifying Benefits

The benefits of a project are often more difficult to identify because benefits are seldom obvious cash flows, but outcomes relating to the objectives of the CBA (CEEU, undated). In agricultural projects benefits and costs can be tangible or intangible. Tangible benefits can arise either from increased value or reduced costs of production. Increased physical production is the most common tangible benefit in agricultural projects (Gittinger, 1982). The benefit from agriculture may also take the form of improvement in the quality of the product. Agricultural projects also have intangible benefits and costs such as creation of new job opportunities, improved health and reduced incidence of environmental costs (Belli *et al.*, 1997). Typical benefits may include among others reduction in health care costs, accident savings, travel time savings, reduced environmental emissions, lower operating and maintenance costs, job creation and increased water quality (CEEU, undated).

Some agricultural projects also benefit from improved marketing facilities that allow for a product to be sold at a time when prices are more favourable. Benefits in investing in transport equipment to carry products from a local area where prices are low to distant markets where prices are high. Benefits from mechanisation that reduce costs by investing in machinery to reduce labour costs and reduced transport costs (Gittinger, 1982). Snowdon and Harou (2013) state that benefits usually come into one of the following categories:

• Impacts which can be quantified in both physical and monetary terms;

• Impacts which can be quantified in physical terms but not easily in monetary terms (for example, hectares of communal land open to public access for grazing); and,

• Impacts which are difficult to quantify (for example, longer term effects on biodiversity or landscape from woodland creation).

3.3. Valuing Costs and benefits

Once costs and benefits have been identified, they must be valued to be compared (Gittinger, 1982). The value of a good is measured by what people are willing to pay or give up from their endowment of resources to acquire one additional unit of that good. Alternatively, value can be represented by what people are willing to accept to tolerate a loss of a unit of the good or to forego a gain of a unit of the good (Panayotou, 1997). Since willingness to accept is not bounded by a budget constraint it is often exaggerated. The project inputs should be valued at their opportunity cost and generally the use of market prices is recommended as they best reflect the opportunity cost involved (CEEU, undated and Panayotou, 1997). In many cases, the value of opportunity cost is reflected in its market price (Snowdon and Harou, 2013). When market prices do not reflect the opportunity cost of inputs and outputs, the usual approach is to convert them into shadow prices (European Commission, 2014), although there should be clear and convincing reasons for doing so (CEEU, undated).

For most of the productive projects, the type and the extent of expected benefits can be quantified through factors such as time and cost savings, increased access, improved health, etc. Most of these benefits have a productive effect, and direct effect on welfare (Desai, 1997). Shadow pricing is defined by Panayotou (1997), as a process of predicting prices that would have prevailed in the absence of policy distortions such as taxes, subsidies, quotas, or overvalued exchanges rates. If some costs cannot be quantified in physical or monetary terms, these should still be noted, and given some weighting which reflects their importance (Snowdon and Harou, 2013). The benefits that cannot be quantified should be stated along with an estimate of the number of beneficiaries (Desai, 1997).

3.4. Measuring Project worth

After the costs and benefits have been identified, priced and valued the project worth must be measured and the decision on which project to accept or reject must be taken. The project that will last several years and have differently shaped future costs and benefit streams and projects of varying size must be evaluated (Gittinger, 1982). This is usually addressed through discounting. Discounting is the process of finding present monetary value of the future income streams. The discount rate applied should represent the opportunity cost of capital (Bizoza and De Graaff, 2012). The discounting measures that are suitable for application in agricultural projects are identified by Gittinger (1982) as net present worth (NPV), internal rate of return (IRR), benefit cost ratio (B/C) and net benefit investment (N/K).

3.4.1. Net Present Value

Costs and benefits occur at different points in the life of the project so the valuation of costs and benefits must take into account the time at which they occur. All costs and benefits should be presented in present value terms through the application of a discount rate (Snowdon and Harou, 2013). Presenting costs and benefits in present value terms take account of time preference; that is, the value that is placed on consuming a good or service nearer in time compared to further in the future, or bearing a cost later rather than sooner (Snowdon and Harou, 2013). By estimating the 'present values' of both costs and benefits, the 'net present value' (NPV) of different options can be compared in order to identify the option that yields the greatest net benefit. The net present value (NPV) is the difference between total benefits and total costs, both discounted at the appropriate discount rate (Maniriho and Bizoza, 2013).

In financial analysis it is the present worth of the income stream accruing to the individual or entity from whose point of view the analysis is being undertaken. In economic analysis it is the present worth of the incremental national income generated by the investment (Gettinger, 1982). Two conditions must be satisfied if a project is to be acceptable on economic grounds: (a) the expected present value of the net benefits of the project must not be negative when discounted at an appropriate rate; and (b) the project's expected NPV must be at least as high as the NPV of mutually exclusive alternatives (Belli *et al*., 1997). The value shows the excess or shortfall of benefits over costs and reflects how much the project will earn. If the NPV is negative, clearly the costs outweigh the benefits and the project is not economically feasible (Hanley and Splash, 1993). The choice entails possibly two types of errors in choosing a profitable project among others.

A higher discount rate decreases the NPV and may lead to rejection of a project which might be a good one and vice versa. A positive NPV indicates a positive net benefit. In case of mutual exclusiveness the project with the highest (positive) NPV is favoured, all other things being equal (Bizoza and De Graaff, 2012). The formal selection criterion for the net present worth measure is to accept all independent projects with zero or greater net present worth when discounted at the opportunity cost of capital (Gittinger, 1982). The NPV is an absolute profitability indicator and, like the IRR, should not be used to rank project alternatives. A small, but profitable project may have a lower NPV than a large, marginally profitable project. The NPV simply shows whether a project should be selected or not. The advantage of the NPV is that it is also applicable in the case of mutually exclusive projects (Bizoza and De Graaff, 2012).

3.4.2. Internal Rate of Return

Alternatively, or in addition to the NPV, the' internal rate of return on capital investment' (IRR) can be calculated (Snowdon and Harou, 2013). The IRR is the discount rate that makes the present value of a project exactly equal to zero (Henley and Splash, 1993). The IRR has the advantage of not having to choose a discount rate. The value of costs and benefits for each year should not include inflation, meaning that, they should be presented in real rather than nominal terms. This is done using GDP data to adjust any nominal data to a constant price year (Snowdon and Harou, 2013). A project can only be acceptable if its IRR is higher than the opportunity cost of the funds involved (Department of Environmental Affairs and Tourism, 2004). The IRR is the maximum interest that the project could pay for resources used if the project is to recover its investment and operating costs and still break-even (Gittinger, 1982).

The IRR can then be compared with a base line or standard rate, for example the current interest rate, or a certain minimum rate, and if the IRR is higher the project would be profitable. Occasionally IRR and NPV may yield a different ranking of projects. The size of projects matters in calculating NPV, large projects with high costs and benefits are likely to have higher NPVs than small projects. This is not the case with IRR. On the other hand it may be difficult to obtain an IRR, when there are no (high) investment sums made in the first years (Bizoza and De Graaff, 2012). The IRR is the most popular profitability indicator, because it is a relative measure that allows a direct comparison between investments and market interest rates (yield). Nevertheless, there are two constraints on its use. Firstly, the use of the IRR in the case of mutually exclusive projects may lead to incorrect recommendations. Mutually exclusive projects occur if implementation of one project makes the other project impossible. Secondly, the IRR cannot be used for ranking project alternatives as it cannot prove that the project with higher rate is better. It does not distinguish between projects of different sizes (CEEU, undated).

3.4.3. Cost Benefit Ratio

Maniriho and Bizoza (2013) define the benefit-cost ratio as the present value of project benefits divided by the present value of project costs, both benefit values and cost values being computed in local currency. It is assumed initially that benefits are gross benefits, and costs are gross costs, which means that all costs (investments and recurrent costs) are added together (Howlett and Nagu, undated). A project is acceptable if B/C ratio is one or greater. Like the IRR, this is a conceptually simple method. However, when comparing mutually exclusive projects, this method is ineffective. The absolute value if B/C ratio will vary depending on the interest rate chosen. The higher the interest rate, the smaller the C/B ratio and if a high enough interest rate is chosen the C/B ratio can be driven to less than one (Gittinger, 1982).

3.4.4. Net Benefit on Investment Ratio

Upon the mentioned discount measures of a project worth none can be relied upon the ranking of projects. In many instances it is convenient to have a reliable measure to rank projects to determine the order in which such projects should be undertaken. If projects could be ranked the ones with highest priority should be chosen. A suitable criterion for ranking independent projects that is reliable in most extreme cases is the benefit investment ratio (N/K). N/K ratio is the present worth of the net benefits divided by the present worth of the investment. It is simply the present worth of net benefits divided by the present worth of investment, expressed as a percentage. When using the N/K ratio in selection criterion all projects with N/K ratio greater or equal to one when they are discounted at the opportunity cost of capital are accepted in order, beginning with the largest ratio value proceeding until the investment funds are exhausted (Gittinger, 1982). This can be used to rank projects that are mutually exclusive only when the net benefits of investment ratios of all projects in the investment program are known.

3.5. Risk and Sensitivity Analysis

Uncertainty and risk are present whenever a project has more than one possible outcome. The measurement of economic costs and benefits, therefore, inevitably involves explicit or implicit probability judgments (Belli *et al*., 1997). Risk should be explicitly identified and their possible or expected impact on the economic viability of the project, and its sustainability, examined. In some circumstances there are only uncertainty. In other cases this can be transformed into 'risk' with an assessment of probability distributions indicating the likelihood of the realised value of a variable falling within stated limits (FAO, 1995). Risk, but not uncertainty, is subject to empirical measurement, and can be analysed and possibly managed. A risk assessment consists of studying the probability that a project will achieve a satisfactory outcome (in terms of some threshold value of the IRR or the NPV).

Probability should be understood as an index that takes the value one under full certainty that a prediction will be confirmed. A zero value for certainty that the prediction will not be confirmed, and intermediate values for anything in between the two extremes. The recommended steps for assessing the project risk are: sensitivity analysis, probability distributions for critical variables, risk analysis, assessment of acceptable levels of risk and risk prevention (European commission, 2008). As uncertainty is often involved, and opinions may differ on the right prices or other assumptions regarding effects. Many CBA studies include a sensitivity analysis (FAO, 1995). Sensitivity analysis is defined by Howlett and Nagu (undated) as a technique where the viability of the project is tested against possible variations in the size and timing of estimated costs and benefits. The calculations of NPV, IRR and B/C are based on estimates of project costs and benefits which are subject to varying uncertainty and risk (Bizoza and De Graaff, 2012). Sensitivity analysis is undertaken to test the robustness of results under different scenarios, using different assumptions for different variables (FAO, 1995).

Sensitivity analysis is a necessary part of any investment appraisal as it can:

- Test the impact of using different discount rates (the agreed rate should be used with sensitivity analysis two or three per cent points ‘above’ and ‘below’ the agreed rate),
- Assess the possible impact of uncertainty,
- Illustrate what would happen if the assumptions made about some variables proved to be wrong and show how changes in the values of various factors affect the overall costs or benefit of a given project, and
- Indicate the critical elements on which the positive outcome of the project depends.

The analysis of how sensitive the project viability is to various changes in variables is done by “switching” values (Bellie *et al.,* 1997). This process recalculates the NPV, IRR and B/C according to “what if” certain variables such as input costs, investment cost and operating costs increase or decrease (Howlett and Nagu, undated). Sensitivity analysis is used to identify the critical variables of the project that have the largest impact on the project’s financial and/or economic performance (European Commission, 2014).

3.6. Typical Farm as an Evaluation Tool

When conducting farm-level research in a relatively large geographical area, the type of data within which to base the analysis is a major challenge. Each farm has its own resources and differs from other farms in various aspects (Feuz and Skold, 1990). Hoffmann (2010) stated that even small farms are complex and unique, and no two farms will have exactly the same factors affecting profitability in precisely the same way. Feuz and Skold (1990) highlighted the collection of individual farm data, or a sample of farms to be analysed, the use of aggregate state or regionally reported data; or the use of synthetic farms where few options available. Kahlon and Singh (1982) referred to these data collection options as basic types of farm situations used to represent a large number of farm situations. Each of these options has its advantages and disadvantages and will be explained further in this chapter.

Individual data: the key to case study is to collect individual data from a farm or a sample of farms to be analysed to study the phenomena the researcher is interested in. From this point of departure, aspects of findings may be extrapolated to the target population in terms of those features that the case study analysis has revealed to be important (FAO, 1994). The advantage to collecting individual farm data is that the subsequent analyses should adequately describe the farm(s) being studied. One should be confident in the results and recommendations for that specific farm or group of farms. The major disadvantages to this method of doing research at the farm level are the time required and the high cost for gathering individual farm data (Feuz and Skold, 1990). Case studies are often chosen to be indicative of the variability found in the target population rather than to be representative of the population (FAO, 1994). Unless the farms were selected from a carefully designed random sample, the potential to make general statistical inferences to a broader group of farms is limited (Feuz and Skold, 1990). The advantage of modelling individual farms include;

- Improved representation of the heterogeneity among farms in terms of policy representation and impacts,
- It provides the most possible disaggregation regarding farms and activities, and
- Reduces aggregation bias in response to policy and market signals (European Commission, 2013).

Aggregate Data: average farm situation is used to represent all farms in the area (Kahlon and Singh, 1992). Farming in many states is quite diverse, and average aggregate data may not be representative of any actual farming area or any particular farm. The major problem with most aggregate data is the question of what it actually represents, or is it representative of any particular farm or group of farms (Feuz and Skold, 1990). The danger in using average farm data arises from the fact that there may be too much variation in the resource structure, organization, and use of farm land. The average farm situation might become an unrepresentative farm (Kahlon and Singh, 1992). Risk cannot be represented accurately with aggregate data because much of the variability faced by individual producers is "averaged out" of county, state or national aggregates. Aggregating and averaging of agricultural production into broad geographic and commodity output groups can lead to misleading perceptions about farm level economic impacts. An advantage to using secondary published data at the state, or other aggregated level, is that the data is relatively inexpensive to obtain (Feuz and Skold, 1990).

Synthetic Farms: Kahlon and Singh (1992) define synthetic farm as a via media between average and actual or model farm situation which are two extremes. A synthetic farm represents an average of a broad category of farms, but not all farms. It cannot be duplicated for any farm situation, suitable adjustments have to be made to tailor it to suite a given farm situation. (Feuz and Skold, 1990) state that synthetic farms are often constructed from economic-engineering machinery budgets, agronomic crop response functions, and livestock production coefficients. The emphasis on structuring synthetic farms is on considering the group of farms with minimum possible variability within itself. This is achieved by considering each agro-economic zone, broad determinant of farm resources structure, organisation and productivity. Then the farms can be clustered into specified groups on the basis of broad determinants or major variables. It is further stated that if the variability in a particular group is too much, averaging for the whole group to form a synthetic farm would be little better than the average farm concept or situation (Kahlon and Singh, 1992). The synthetic farm offer the advantage of relatively inexpensive data collection and data that should not be biased by peculiar management practices one may find with sample data. While these synthetic farms may represent what could or should be, they often overstate what actually is (Feuz and Skold, 1990).

One method of avoiding the possibility of average bias from aggregate data is to develop sets of typical farms. The typical farms are modal farms, or may be thought of as case farms, and they can be real or synthetic (Feuz and Skold, 1990). FAO (1994) show that a representative farm is typically defined in terms of mean, modal or median values for selected parameters such as absolute or relative resource endowments. Hoffmann (2010) define typical farm as a tool that can be used to assess farm profitability and to determine the effect of variations in a range of variables on farm-level profitability. The important characteristic of typical farms is that the resource base and the technological constraints are typical and are not the average of a group of farms. The concept of a typical farm has been used since the late twenties and early thirties. Typical farms provide information such as typical sizes in different regions, the most common mix of enterprises, combination of capital items required for production and economic measures of economic being of a farm (Hatch *et a*., 1982).

The idea of using typical farms, or more generally representative farms, as a point of departure in doing economic analysis has been described in economic literature for some time and it allows the use of census data and other secondary data available (Feuz and Skold, 1990). A typical farm is usually not a real farm and results do not apply specifically to one actual farm but to a group of farms (FAO, 1994). However, typical farm modelling allows evaluation and comparison of the effect of various managerial decisions and options (Hoffmann, 2010). Farm level impacts of alternative economic environments and agricultural policies can be evaluated through the use of typical farm analysis. Economic analysis of typical farms is useful in applied agricultural research because agricultural policymakers and analysts have a particular need for information on policy impacts and indicators of well-being at the farm level (Hatch *et al*., 1982). An advantage of using typical farm models is that it is a cost and time efficient research method compared to surveys (Hoffmann, 2010). Budget models for typical farms to establish the current environmental sustainability will be developed. The criteria followed in the development of the typical farms will be explained later in this chapter.

3.7. Conclusion

Cost benefit analysis as a technique is used to measure the environmental costs against benefits to assess the environmental sustainability of extensive beef production by commercial and small holder farmers in South Africa. CBA involves identifying and valuing the costs and benefits of the projects, analysis of financial aspects, economic aspects, risk and analysis of a project. The decision maker before making a decision need clarity on whether the project will be profitable, contributes to economic efficiency in the sense that it improves the allocation of scarce resources and it is worthwhile from the point of the group of people that the decision make represents. Financial analysis is concerned with the private profitability, whereas economic analysis is concerned with the economic welfare of the society.

The major challenge when conducting farm-level research in a relatively large geographical area, is the type of data within which to base the analysis on. Each farm no matter how small or big differs from other farms in various aspects and no two farms will have exactly the same factors affecting profitability in precisely the same way. The collection of individual farm data, or a sample of farms to be analysed, the use of aggregate state or regionally reported data; or the use of synthetic farms are highlighted as few options available when conducting farm level research. All of these have its advantages and disadvantages. The advantage of individual data is that it represent an improved heterogeneity among farms and reduces aggregation bias. However, it expensive and time consuming to collect individual data. The use of aggregate data is inexpensive as it allows the use secondary data, but the viability faces by individual producers is averaged out of country, state or national aggregates. Synthetic farms can represent what could or should be but the challenge is that it often overstate what actually is. Development of typical farms profiles has been suggested as one method of avoiding the possibilities of average bias from aggregate data. Using typical farm models is that it is a cost and time efficient research method compared to surveys. Typical farm profiles and budget models will be developed in the next chapter and cost-benefit ratios will be calculated. The sensitivity analysis will be done in three scenarios to test the sensitivity of environmental sustainability to feed efficiency and improvement in management practices.

4. RESULTS AND ANALYSIS

4.1. Introduction

In this chapter methodology application will be explained in detail. Typical farm profiles will be developed and environmental demand for both commercial and small scale farmers will be estimated using secondary data. Budget models for two typical farms will be developed and the results will be analysed. Sensitivity test and analysis will be done on three scenarios. The developed farm profiles will be used as base scenarios for both commercial and communal farm. In the second scenario there is an improvement in food efficiency resulting in improvement of average daily gain by 15% in both commercial and communal farmer. The communal farmer also improve the calving percentage to 40%, mortality rate of 15% and take off percentage of 32%. The commercial farmer improved only feed efficiency. Scenario three the efficiency improves by 20% and productivity improved resulting to a calving percentage of 44% in the communal farmer and 62 % in the commercial farmer everything else remain the same as in scenario two. The results from these different scenarios will be analysed. Sensitivity of the benefits against environmental costs and improved take-off percentage will be tested and analysed.

4.2. Methodology Application

More disaggregated analysis of the economic and environmental impacts by farm type (e.g. specialization, size) and by geographical localisation can only be handled by models working at farm level. These models are able to provide very detailed results at individual/ farm-type level and to capture heterogeneity across farms in terms of policy representation and impacts. The more localised and farm-specific interventions are, the more the modelling of farm-level elements becomes important. Farm level models can better model key issues such as climate change impact, adaptation and mitigation, technological innovation, structural change, farm investment decision and risk management. Models can easily be handled with standard computer packages, including spreadsheets and more sophisticated packages. One of the main limitations of farm models is, often, the lack of interaction. Farm level models vary in terms of whether modelled farms are based on individual (real) farms or on farm-group or representative farm. The type of farm modelling approach to choose depends often on data availability, model specification and research scope (European Commission, 2013). An economic cost benefit analysis of typical farms will be done to assess the environmental sustainability of small scale and commercial beef farmers in South Africa. This section will explain how the model was applied. The methodology application is graphically presented in Figure 4.1.

Extensive commercial and small scale/communal typical farm profiles will be developed. A typical farm is a tool that can be used to assess farm profitability and to determine the effect of variations in a range of variables on farm-level profitability (Hoffmann, 2010). The concept of typical farms has been used since late twenties and early thirties (Hatch *et al*., 1982). It allows the evaluation and comparison of the effect of various managerial decisions and options (Hoffmann, 2010). Secondary data has been used to develop typical farm profiles. Cattle population, and herd structure data was sourced from DAFF (2015) agricultural statistics and from the literature. Country specific emission factors to calculate GHG emission factors were sourced from the literature. This data has been used to calculate GHG/kg beef produced, water/kg beef produced, biomass consumed/kg beef produced and to develop typical farm profiles. Three measurable indicators are used to determine the environmental demand per production system, namely:

- GHG/kg beef produced (yield) under various farming systems
- water/kg beef produced (yield) under various farming systems
- biomass consumed/kg beef produced (yield) under various farming systems

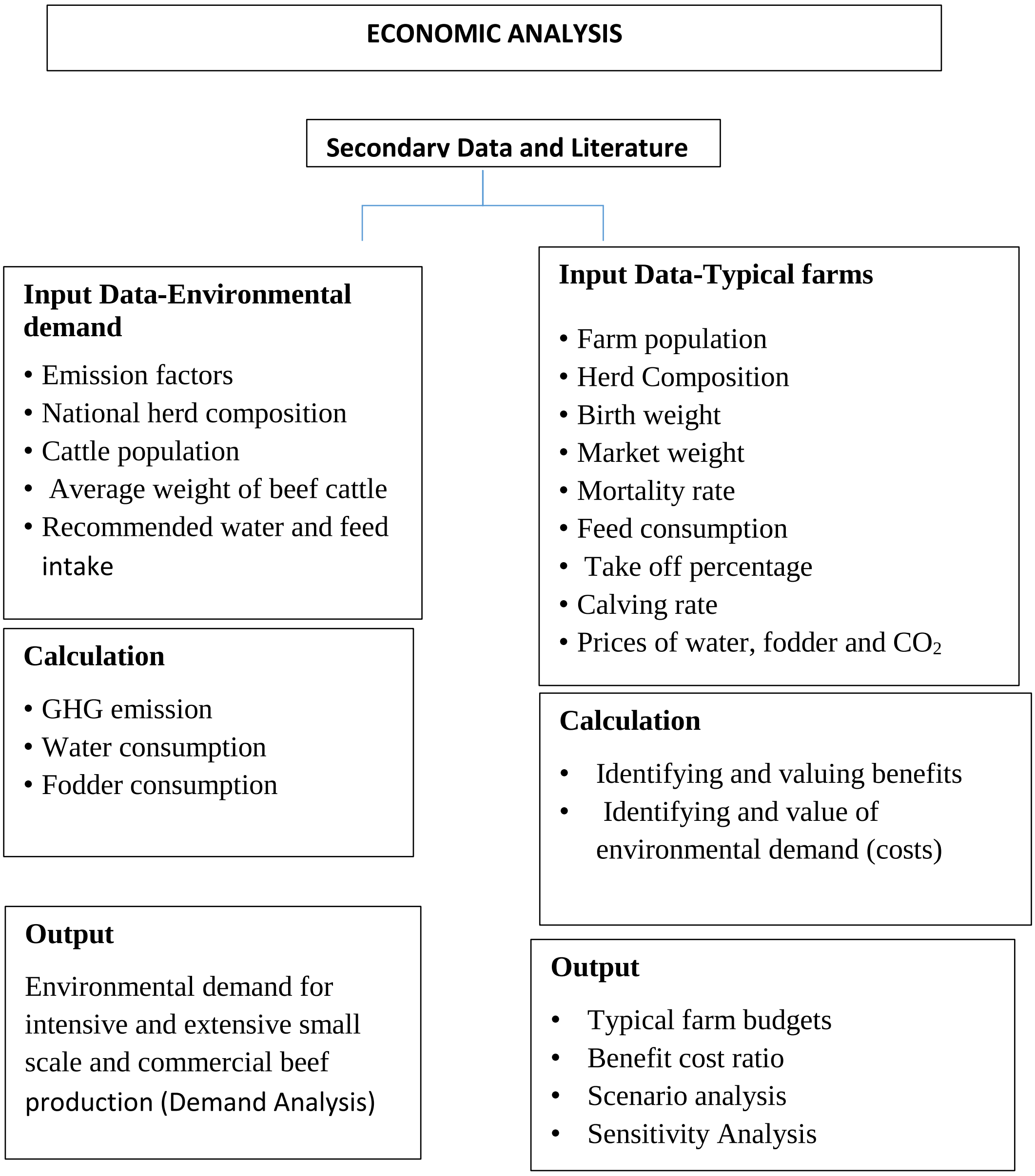

Figure 4.1. Graphically Representation of the Methodology

4.3. Environmental Demand

4.3.1.1. GHG emission

The methods of calculating greenhouse gas (GHG) emissions are based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The emission factors specific to the South African conditions and management systems in Tables 4.1, 4.2 and 4.3 were used in calculating GHG emissions. These emission factors were sourced from the study that was conducted by Du Toit *et al.* (2013). In calculating emission factors Du Toit *et al.* (2013) used a Tier 2 approach for all major cattle sectors in accordance with 2006 IPPC good practise requirements. In calculating the total GHG emissions, the latest national cattle population data and the herd structure of the commercial sector sourced from DAFF (2015), feedlot population sourced from SAFA (2015) were used. GHG emissions were calculated based on cattle population data and herd structure from DAFF (2015). The total GHG emission the total demand is recorded on table 3.4. The formulas used to calculate GHG emissions are as follows:

CH_4 enteric = EF_T * N_T --Equation 3.3.1

CH_4 manure = EF_T * N_T ---------------------------------------Equation 3.3.2

N_2O = EF_T*N_T---Equation 3.3.3

Total E = $\sum E_i$ ---Equation 3.3.4

CH_4 enteric =Methane emission from enteric fermentation

CH_4 manure = Methane emission from manure

N_2O=Nitrous Oxide

EF_T= Emission Factor for the category

N_T= Number of livestock in the category

Total E= Total emission

The total demand is the sum methane emission Nitrous oxide is multiplied by 25 and 95 respectively to convert it to CO_2 equivalent.

Table 4.1: Methane emission factors (MEF) for extensive commercial beef cattle

Animal class	**Average weight (kg)**	**MEF (enteric fermentation)**	**MEF (manure)**
		kg/head/year	**kg/head/year**
Bulls	733	113	0.022
Cows	475	92.6	0.018
Heifers	365	75.9	0.016
Oxen	430	89.4	0.018
Young oxen	193	51.6	0.012
Calves	190	51.6	0.012

Source: Du Toit *et al.* (2013)

Table 4.2: Direct Methane Emission and Nitrous Oxide emission factors for South African feedlot cattle

Animal Class	**Average Weight**	**MEF (enteric fermentation)**	**MEF (manure)**	**Nitrous Oxide**
	Kg	**kg/head/year**	**kg/head/year**	**kg/head/year**
Growing animal	335	58.9	0.87	0.475

Source: Du Toit *et al*. (2013)

Table 4.3: Methane emission factors for extensive communal beef cattle

Animal class	**Weight (kg)**	**MEF (enteric fermentation)**	**MEF (manure)**
		kg/head/year	**kg/head/year**
Bulls	**462**	**83.8**	**0.017**
Cows	**360**	**73.1**	**0.015**
Heifers	**292**	**62.5**	**0.013**
Oxen	**344**	**72.6**	**0.015**
Young oxen	**154**	**41.6**	**0.01**
Calves	**152**	**40.9**	**0.01**
Average		**62.417**	**0.013**

Source: Du Toit *et al*. (2013)

Table 4.4: GHG emissions for beef cattle production systems

Production system	**Population**	**CH4 enteric (ton)**	**CH4 Manure (ton)**	**Nitrous oxide (ton)**	**CO_2 equiv. (ton)**
Feedlot	1 350 000	79 515	1 175	641	2 208 330
Extensive communal/emerging	5 675 600	399 702	83	-	9 994 628
Extensive commercial	5 630 000	530 419	110	-	13 263 215
Total	12 655 600	1 009 636	1 367	641	25 466 173

4.3.1.2. Water consumption

Agriculture consumes about 75% of the fresh water in South Africa, 60% is utilised by the natural vegetation, 12% by dry land crop production and three percent by irrigation (RPO & NERPO, 2014). Livestock consume large quantities of water in the production of beef or milk. The water footprint depends on production system and its efficiency. The overall demand for water in livestock production is influenced by several factors which include feed intake and diet, quality of available water, temperature of water, and the temperature of the ambient environment (Ran, 2010). Table 4.5, 4.6 and 4.7 show the estimates of water footprint in each production system. The amount of water required to produce one kilogram of beef include; drinking water and water used to produce feed.

RPO & NERPO (2014) recommends intake of three to four litres of water per kg of dry feed intake therefore an average of 3.5 litres is used in calculating drinking water per animal. Du Toit *et al*., (2013) calculated dry matter intake in commercial cattle as 1.3% to 2.6% of body weight (BW). The intake for communal cattle from 1.6% to 2.7% of BW and feedlot cattle intake was estimated at 2.5% of BW. For this study three percent of BW dry mater in take is used in drinking water estimates as it is a recommended norm. The requirement of high energy proportion feed in feedlots is provided in the form of maize, hominy chop or one of the other grains (Spies, 2011). Du Plessis (2003) state that 250 litres of water is needed to produce one plant of maize which is estimated to produce 0.35kg of maize. Rust *et al*. (2019) indicated that during winter months 51% of extensive beef farmers provide their animals with extra feed. About 49% of farmers are buying forage and 13% were feeding their cattle farm produced forage in winter months or during draught (Katikati, 2017). Based on these findings it is assumed that 20% of the feed provided by commercial farmers is planted Lucerne. In Lucerne production 0.775 litres of water is needed to produce one kg of Lucerne (De Kock, 2012).

Table 4.5: Water consumption estimates for commercial extensive beef production

Animal Class	**Weight (kg)**	**Drinking water per head (l/day)**	**Water used to produce feed (l/day/head)**	**Total water use (l / head / day)**	**Total water use (l / head / year)**
Bulls	733	77.0	3.41	80	29 336
Cows	475	49.9	2.21	52	19 011
Heifers	365	38.3	1.70	40	14 608
Oxen	430	45.2	2.00	47	17 210
Young oxen	193	20.3	0.90	21	7 724
Calves	190	20.0	0.88	21	7 604

Table 4.6: Water consumption estimates for communal extensive beef production

Animal Class	**Weight (kg)**	**drinking water per head (l/day)**	**Water used to produce feed (l/day/head)**	**Total water use (l / head / day)**	**Total water use (l / head / year)**
Bulls	462	49	0	49	17 706
Cows	360	38	0	38	13 797
Heifers	292	31	0	31	11 191
Oxen	344	36	0	36	13 184
Young oxen	154	16	0	16	5 902
Calves	152	16	0	16	5 825

Table 4.7: Water consumption estimates for feedlot beef production

	Weight (kg)	**drinking water (l/day/head)**	**water use for feed/head (l/day)**	**Total water use (l / head / day)**	**Total water use (l / head / year)**
Growing animal	335	35.2	7 179	7 214	649 237.18

A growing animal under feedlot system with average weight of 335kg would drink 35.2 litres per day and 7179 litres is needed to produce 10.05 kg dry matter intake (feed) per day.

Table 4.8: Water demand by beef cattle

Sector	**Population**	**Water use/year (m^3)**
Extensive commercial	5 630 000	109 899 498
Extensive communal	5 675 600	63 950 106.78

4.3.1.3. ***Biomass consumption***

Feed consumption for commercial, communal and feedlot famers are estimated in Table 4.9, 4.10 and 4.11 respectively. Feed efficiency depends on the average daily gain (ADG) and feed conversion ratio of an animal (FCR). ADG is influenced by the quantity of the feed ration and the quality of the animal on feed (Spies, 2011). FCR and ADG were also estimated in Table 4.9 and 4.10 to determine the amount of feed needed to produce one kg of beef in different production systems. ADG is computed as the final weight of an animal less its birth weight divided days of growth to reach the final weight. The FCR is calculated as the ADG divided by the feed consumption per day. Biomass consumption is valued at R871/ton (Blignaut *et al*., 2017).

Table 4.9: Feed consumption estimates for Commercial beef cattle

Animal Class	Weight (kg)	%daily intake	Consumption (kg/head/day)	Consumption (kg/head/year)	Average daily gain (calves)	Feed conversion ratio
Bulls	733	3%	22.0	8026	0.72	7.87
Cows	475	3%	14.3	5201		
Heifers	365	3%	11.0	3997		
Oxen	430	3%	12.9	4709		
Young oxen	193	3%	5.8	2113		
Calves	190	3%	5.7	2081		
Average	398		11.9	4354		

Table 4.10: Feed consumption estimates for communal beef cattle

Animal Class	Weight (kg)	%daily intake	Consumption (kg/head/day)	Consumption (kg/head/year)	Average daily gain (calves)	Feed conversion ratio (calves)
Bulls	462	3%	13.9	5059	0.36	12.70
Cows	360	3%	10.8	3 942		
Heifers	292	3%	8.8	3 197		
Oxen	344	3%	10.3	3 767		
Young oxen	154	3%	4.6	1 686		
Calves	152	3%	4.6	1 664		
Average	294		8.8	3219.30		

Table 4.11: Feed consumption estimates for feedlot cattle

Animal Class	**Weight (kg)**	**%daily intake**	**Consumption (kg/head/day)**	**Average daily gain**	**Feed conversion ratio**
Growing animal	335	3%	10.05	1.89	5.3309

4.4. Typical farm profiles

The average total population of 413 for a typical commercial farm has been sourced from Scholtz *et al.* (2008), herd composition has been derived from DAFF (2015) livestock statistics by dividing each herd by the annual total population and the average weights have been sourced from Du Toit *et al*. (2013). Table 4.12 and 4.13 represent the herd composition and description of extensive commercial farm. Table 4.14 and 4.15 represent the herd composition and the description of communal / small scale extensive beef farm. The information in these tables will be used in developing budget models to measure production benefits against environmental costs in each farming category.

Table 4.12: Herd composition of an extensive commercial farmer

Description	Population	Weight
Total population	413	
No. Cows over 2 years	157	475
Heifers	50	365
Bulls	11	733
Oxen	46	430
Young Oxen	47	193
Calves	102	190

Table 4.13: Commercial farm description

Description	Value	Reference
Birth Weight	35	Niemond, 2013
Market Age	214	Spies, 2011
Feed consumption/day	0.026	Du Toit *et al*. 2013
Calving %	0.55	Scholtz and Bester, 2010
Mortality	0.058	Meissener *et al*. 2013
Take-off %	32%	Scholtz and Bester, 2010
Calf Price /kg	R19.96	SAFA, 2016
Cattle price/kg	R22.75	SAFA, 2016
Fodder Price/ ton	R871	Blignaut *et al*., 2017
GHG Price /ton	R120	National Treasury, 2013
Water Price/m^3	R2	Blignaut *et al*., 2017

Table 4.14: Herd composition of an extensive communal farmer

Description	Population	Weight
Total population	19	
No. Cows over 2 years	7	360
Heifers	2	292
Bulls	1	462
Oxen	2	344
Young Oxen	2	154
Calves	5	152

Deduced from Daff (2015)

Table 4.15: Communal farm description

Description	Value	Reference
Birth Weight	31	Niemond, 2013
Market Age	336	Webb and Erasmus, 2013
Feed consumption/day	0.027	Du Toit *et al*., 2013
Calving %	35%	Scholtz and Bester, 2010
Mortality	35%	Meissener *et al*., 2013
Take off %	6.00%	Scholtz and Bester, 2010
Calf Price/kg	19.96	SAFA, 2016
Cattle price/kg	R22.75	SAFA, 2016
Fodder Price/ ton	R871	Blignaut *et al*., 2017
GHG Price /ton	R120	National Treasury, 2013
Water Price/m^3	R2	Blignaut *et al*., 2017

4.5. Scenarios

To test the impact on the financial benefit a number of scenarios were developed. Scenarios are simply "what if?" statements and is used to explore possible future outcomes for a specific issue. Three scenarios were modelled. The first scenario will be the base scenario with the above description. In the second scenario there is an improvement in food efficiency resulting in improvement of average daily gain by 15% in both commercial and communal farmer. The communal farmer graduates to emerging farmer with the calving percentage of 40%, mortality rate of 15% and take off percentage of 32%. The commercial farmer improved only feed efficiency. Scenario three the efficiency improves by 20% and productivity ii improved resulting to a calving percentage of 44% in the communal farmer and 62 % in the commercial farmer everything else remain the same as in scenario two.

4.6. Farm Budget Models

The budget models of two typical farms that distinguish between two production systems (extensive commercial and communal) and three scenarios of each were developed based on the farm profiles in Paragraphs 3.4 and 3.5.

Table 4.16: Commercial Farm Budget Model

Income	Scenario 1	Scenario 2	Scenario 3
Cows	R 544 253.53	R 544 253.53	R 792 179.17
Heifers	R 133 640.41	R 133 640.41	R 146 094.52
Bulls	R 0.00	R 0.00	R 0.00
Oxen	R 144 473.79	R 144 473.79	R 43 027.84
Young Oxen	R 57 622.16	R 63 668.01	R 26 210.62
Weaners	R 123 505.75	R 138 618.96	R 182 238.69
Gross Income	**R 1 003 495.65**	**R 1 024 654.70**	**R 1 189 750.83**

Environmental costs			
Calves			
Fodder	R 57 773.27	R 61 424.60	R 72 791.71
Water	R 383.45	R 383.45	R 454.41
GHG	R 9 236.66	R 9 236.66	R 10 945.98
Cows			
Fodder	R 641 363.91	R 617 951.29	R 810 770.68
Water	R 4 253.70	R 4 253.70	R 5 580.98
GHG	R 43 731.35	R 43 731.35	R 57 376.85
Oxen			
Fodder	R 170 252.04	R 164 037.09	R 44 037.65
Water	R 1 129.99	R 1 129.99	R 303.36
GHG	R 12 380.42	R 12 380.42	R 3 323.67
Young oxen			
Fodder	R 27 378.34	R 26 378.91	R 9 788.91
Water	R181.71	R 181.71	R 67.43
GHG	R 4 322.72	R 4 322.72	R 1 604.11
Bulls			
Fodder	R 66 606.94	R 64 175.50	R 41 476.39
Water	R 444.52	R 444.52	R 287.29
GHG	R 3 611.20	R 3 611.20	R 3 611.20
Total Costs	**R 1 043 050.23**	**R 1 013 643.11**	**R 1 062 420.61**
Loss or Profit	**-R 39 554.59**	**R 11 011.59**	**R 127 330.22**
C/B	0.96	1.01	1.11984916

Table 4.17: Communal farm budget

Income			
Cows	R 3 558.07	R 21 180.34	R 23 510.18
Heifers	922.2159026	R 5 489.73	R 6 093.60
Bulls	630.63	R 0.00	R 0.00
Oxen	996.9740974	R 5 934.74	R 6 587.57
Young Oxen	396.6046281	R 2 601.43	R 2 620.59
Weaners	852.2794178	R 5 074.50	R 5 632.70
Gross Income	R 7 356.78	R 40 280.74	R 44 444.63

Environmental costs			
Calves			
Fodder	R 3 399.12	R 3 719.94	R 3 719.94
Water	R 6.79	R 25.63	R 25.63
GHG	R 574.62	R 574.62	R 667.34
Cows			
Fodder	R 22 374.69	R 24 973.33	R 24 973.33
Water	R 203.37	R 172.03	R 172.03
GHG	R 1 588.21	R 1 588.21	R 1 588.21
Oxen			
Fodder	R 6 269.40	R 6 997.54	R 6 997.54
Water	R 43.19	R 48.20	R 48.20
GHG	R 462.53	R 462.53	R 462.53
Young oxen			
Fodder	R 2 842.63	R 3 172.78	R 3 172.78
Water	R 19.58	R 21.86	R 21.86
GHG	R 268.44	R 268.44	R 268.44
Bulls			
Fodder	R 3 965.67	R 4 426.25	R 4 426.25
Water	R 27.32	R 30.49	R 30.49
GHG	R 251.45	R 251.45	R 251.45
Heifers			
Fodder	R 5 799.29	R 6 472.83	R 6 472.83
Water	R 39.95	R 44.59	R 44.59
GHG	R 433.92	R 433.92	R 433.92
Total	R 48 570.16	R 53 684.63	R 53 777.35
Loss or Profit	-R 41 213.38	-R 13 403.89	-R 9 332.72
	0.151467037	0.75	0.83

4.7. Analysis of Results

4.7.1. Environmental Demand

4.7.1.1. GHS Emission

The communal sector emits approximately 9 994 682 tons of Carbon dioxide per annum, meaning that each animal emits an average of 1.7610 tons of CO_2 per annum in the communal sector. CO_2 equivalence is calculated in Table 3.4 as 25 times methane emission. The commercial sector produces 11 123 895 tons of CO_2 per annum, which is equivalent to an average of 1.9758 per animal per annum. This shows that more GHG is emitted by the commercial extensive commercial farmers compared to communal farmers, however when looking at GHG emitted per kg of meat produced per annum the commercial sector emits less GHG per kg of live weight compared to communal farmers. For example in a communal sector a cow with an average weight of 360 kg emits 1.828 tons of $C0_2$ per annum, which is equivalent to 0.0051 tons of $C0_2$ per kg of live weight. In a commercial sector a cow with an average weight of 475 kg emits 2.315 ton of CO_2 per annum, which is equivalent to 0.0048 tons per kg of live weight.

4.7.1.2. Water Consumption

The communal sector consumes 63 950 106.78 m^3 of water per annum, and commercial sector consumes 109 899 498 with an assumption that 20% of the feed is planted Lucerne. More water is used by commercial compared to communal sector. In average each animal in a communal sector consumes 11.238 m^3 and 19.520 m^3 per annum in the commercial sector. The amount of water consumption depends on the feed consumption and weight of an animal, therefore these differences might be because of the difference in weight and feed consumption in these sectors and also the fact that commercial sector also make use of planted Lucerne. In a commercial sector a cow with an average weight of 475 kg consumes 19.011 m^3 of water per annum; therefore for each kg of live weight 0.04 m^3 is needed. In a communal sector a cow with an average weight of 360 kg consumes 13.797 m^3 per annum; therefore 0.038 m^3 is needed per kg. More water is needed per kg beef produced in a commercial sector than in communal sector.

4.7.1.3. Biomass

Feed consumption depends on the weight of an animal. An animal is required to consume three percent dry matter of its body weight per day. Animals with high body weight consume more feed, which in this study will be animals in commercial sector. The most important thing under this section is feed efficiency, which is defined as an amount of feed consumed by an animal converted to meat. To measure efficiency an average daily gain and feed conversion ratio were calculated in Tables 4.9, 4.10 and 4.11. Average daily gain has been calculated by subtracting the birth weight from the finish weight and divide by the number of growth days. The feed conversion ratio is calculated by dividing feed consumption of a calf per day by an average daily gain. If the birth weight of a calf in commercial sector is 35 kg and is reared for 214 days to reach weight of 190 kg, the average daily gain would be 0.72 kg. A calf gain one kilogram weight would need 7.87 kg of dry matter intake.

A calf in the communal sector born with an average weight of 31.4 kg is reared for 336 days to reach weight of 152 kg. The average daily gain would be 0.36 kg per day and 12.70 kg of dry matter intake is needed to produce one kg live weight. Commercial sector uses feed more efficiently than in communal sector as more feed is needed in the communal sector to produce one kg than in commercial sector. This might be due to different factors such has the quality of feed, breed type, energy needed by an animal to reach feed and water per day.

4.7.2. Budget model and Scenario Analysis

Typical farms were identified and budget models were developed and this showed the current situation of extensive beef production. The aim was to assess the benefits over environmental costs in order to measure the environmental sustainability of different extensive beef production systems in South Africa. These typical farm budget models were developed based on secondary data and literature reviews. The purpose of the budgets is to measure environmental costs against the benefits which in this case will be income from sales of animals and costs will the monetary value of GHG, water use and biomass consumption. Average prices of the previous years were used in calculating income. Both commercial and communal farmer herds are characterised by 2.5% of bulls, 38% of cows older than two years, 12% heifers, 24% calves, 11% young oxen and 11% oxen older than two years.

A commercial system as described in the scenario represents the current farming practises. This systems showed a C/B ratio of 0.96 meaning that the environmental costs outweigh the benefits by four percent. This shows that the current production methods or management practises employed by commercial extensive farmers are not environmental sustainable. An improvement in management practises that would result in efficiency of 15% average daily gain show a positive C/B of 1.01 which is equivalent to a gross margin of R11 011.59 in Scenario two. An improvement in Scenario three of calving percentage from 55% to 62% and take-off from 32% to 36% and an average daily gain increase by 20% would result in benefits of 1.12% equivalent to a gross margin of R127 326.

A communal farmer with 19 cattle in scenario one has a C/B ratio of 0.15 showing a loss 85% equivalent to -R 41 213.38. An improvement in management practises resulting in increase of 15% in average daily gain, 40% calving rate, 32% take-off and a decrease in mortality from 35% to 15% show an improvement in C/B ratio to 0.75 representing a short fall of 25% equivalent to a loss of –R13 043.89 per annum shown in Scenario two. A further improvement to 44% calving rate, 36% take off and 20% average daily weight gain still show a loss of 17% in scenario three. More improvement is needed by communal farmers to be environmentally sustainable.

4.7.3. Sensitivity Analysis

Sensitivity analysis assesses risks by identifying the variables that most influence a project's net benefits and quantifying the extent of their influence. The identified critical variables on the farm's gross margin are environmental cost and sale of animals. Sensitivity analysis on variation of improvement in animal sales (takeoff) and a decrease on environmental costs of five percent, 10%, 15% and 20% was performed. If the communal farmer can improve takeoff percentages by five percent to 20% the cost benefit ratio would still be less than one. The communal farmer will only realize benefits when the takeoff percentage is approximately 36.8%, which is equivalent to seven animals per annum. A decrease environmental costs only from five percent to 20% would also not result in positive benefits. When improving both the environmental costs and take-off percentage, the benefits can be realised when the take-off is 32% and the environmental costs are lower by 10%. The sensitivity analysis for a communal farmer graphically shown in Figure 4.2.

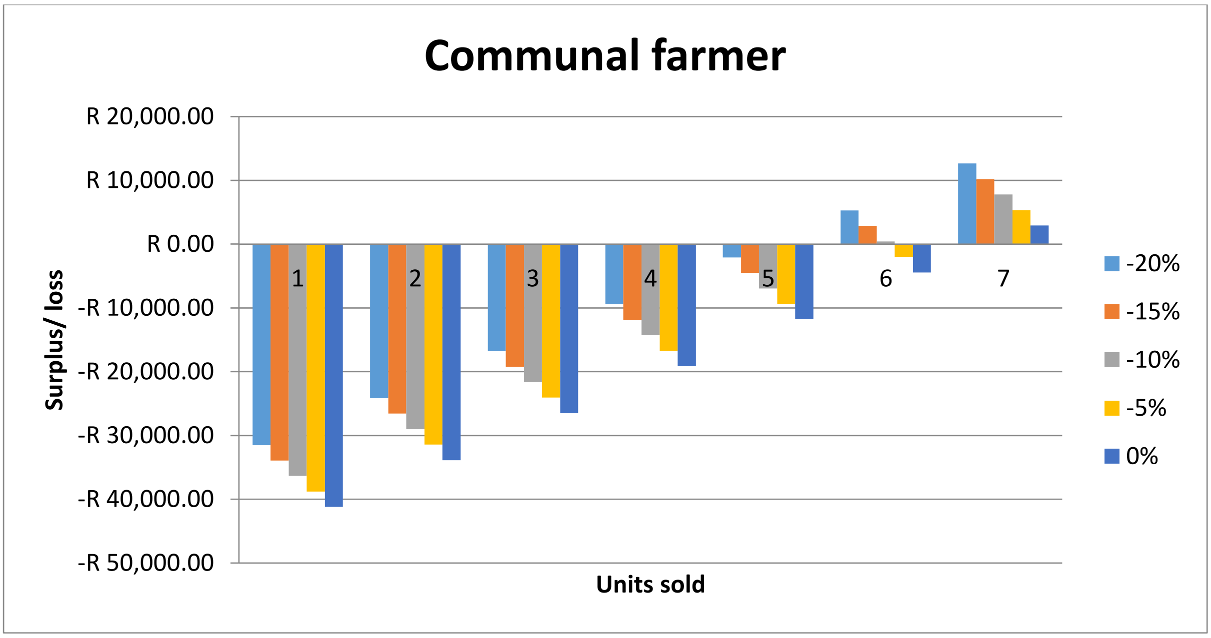

Figure 4.2: Communal Farmer Sensitivity Analysis

Figure 4.3 shows that in a commercial farm both five percent increase in take-off and five percent decrease in environmental costs would results positive cost benefit ratio. However benefits of decreasing environmental costs only would be higher than of increasing take-off percentage only. If a commercial farmer increases take off by five percent to 135 units per annum the gross margin would be R10 620.20, with five percent decrease in environmental costs the gross margin would be R12 597.93.

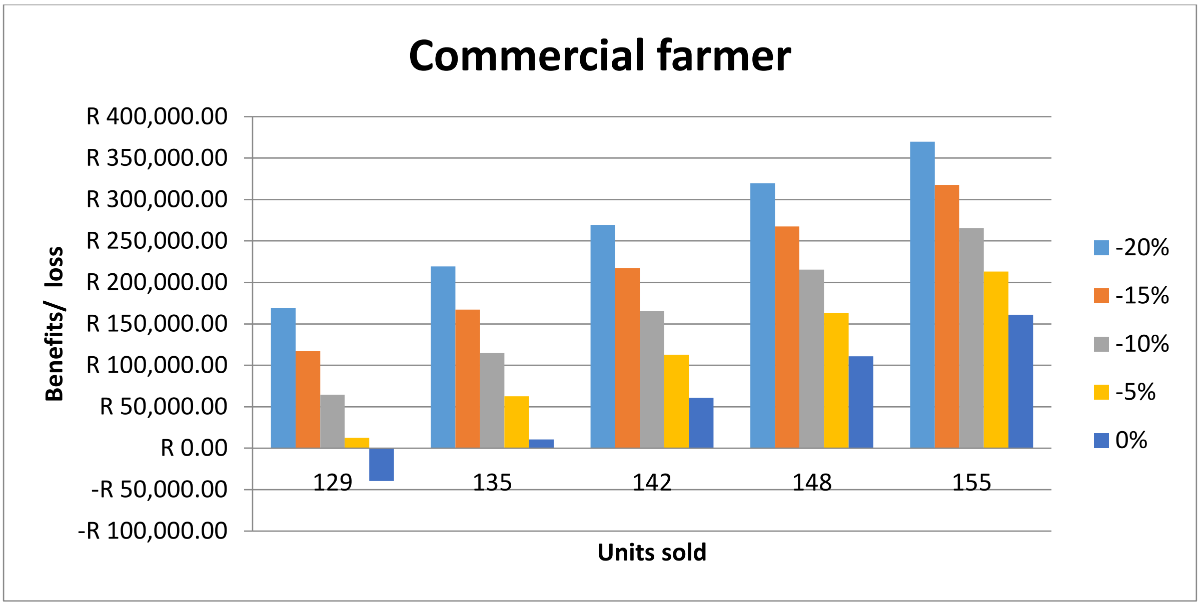

Figure 4.3: Commercial Farmer Sensitivity Analysis

4.8. Conclusion

In South Africa approximately 80% of the land is utilised for agriculture with almost 70% mainly suitable for livestock production. This makes livestock production one of the most important farming practises in South Africa. The livestock industry is facing a challenge of producing sufficient animal protein to supply needs of the growing global population, whilst reducing the negative environmental impact. The increase in food production would have additional environmental consequences on top of the existing environmental demand. The environmental demand include biomass and water consumption and GHG emissions. Green House Gas emissions directly or indirectly linked to livestock production include $C0_2$, CH_4 and N_2O. Livestock production is said to carry the largest carbon foot print (GHG emission) compared with other foods, cattle being a major contributing source of methane emission. A number of studies have concluded that extensive beef production has more environmental demand compared to intensive beef production. However extensive beef production in South Africa is produced at different levels of production by different categories of farmers which include commercial and communal or small holder farmers and each farm is unique.

Sustainable agricultural practices are encouraged as solution to the challenge of increasing of producing sufficient protein while reducing negative environment impact. The main objective of the study is to assess the economic sustainability of extensive beef production at different production levels in South Africa. Economic sustainability emphasises growth and efficient use of resources. To measure efficient use of resources and growth cost benefit analysis of typical farms was uses as a measuring tool. The objective of the study was achieved by estimating total environmental demand for each category of farmers first, measuring GHG emission per kg of beef produced, water per kg of beef produced, biomass consumed per kg of beef produced in category of farmers. Secondary data was used for cattle population and herd structures and emission factors for beef cattle were sourced from the literature. GHG emission was calculated using the 2006 IPCC guidelines for national greenhouse gas inventories. - Feed consumption efficiency is estimated by calculating average daily gain and feed conversion ratio. Typical farm profiles for commercial and small scale extensive beef producers using collective data from the literature were developed. Budget models for both commercial and communal extensive beef farmers were developed and cost benefit ratio was calculated.

The results show that the total demand for GHG emission and biomass are higher in commercial beef production farming systems than in communal farming systems. However, when measured per kg of beef produced commercial farmer demand less GHG and biomass compared to a communal farmer. A commercial farmer demands more water per kg of beef produced than the communal farmer. This might be because of the higher weight of animals in the commercial farms and the fact that the commercial farmer also make use of planted feed. The developed budget models with three scenarios for both commercial and communal farmers show that both current production system have more environmental demand compared to benefits. The benefits are measured by kilograms of beef produced. With improvement of efficiency in resource use the budgets show that the environmental demand can be reduced without decreasing production. The sensitivity analysis show that the environmental sustainability is more sensitive on efficient use of resources that an increase in take-off percentage.

5. CONCLUSION, SUMMARY AND RECOMMENDATIONS

5.1. Conclusion

The livestock industry is faced with the challenge of increasing production to meet the demand of the growing global population, whilst reducing environmental demand and adapting to climate change. The increase in production will expectedly have additional environmental demand consequences. Environmental demand include GHG emission, as well as water and fodder consumption. Livestock has been recognised as the largest contributor in agriculture to climate change, being responsible for 14% of all GHG emissions globally. Nitrous oxide, methane are the main GHG emitted by the livestock industry. Methane has a global warming potential of 25 time than carbon dioxide and nitrous oxide has a global warming potential of 298 times than carbon dioxide. Greenhouse gas emission from extensive beef production is higher than that of intensive beef production systems. South Africa is a water scarce country with highly variable climate. Agriculture consumes about 70% of the fresh water in South Africa and 60% is consumed by natural vegetation. Livestock consume large quantities of water in the production of beef and milk.

A number of studies have concluded that extensive beef production has more environmental demand than intensive beef product. Extensive beef production in South Africa is produced at different levels by different categories of farmers and the farmers are different from each other with different managements systems and resources. Sustainable agricultural practices are encouraged as a solution to the challenge of increasing production and decreasing negative environmental impacts. Sustainability has three pillars social sustainability, ecological sustainability and economic sustainability. Social sustainability is concerned about the extent in which society's needs are met. Ecological sustainability focuses on environmental protection and altitude towards it. Economic sustainability emphasises growth and efficient use of resources. The aim of this study is to measure the economic sustainability of extensive beef production at different levels of production. The human well-being of the present and future generation depends on how society uses its resources.

In a neoclassical approach and in terms of Pareto resource use is efficient when it maximises the well fare of the society. The best known and uses indicators to express efficiency is productivity, allocation and consumption of natural resources, rate of return and profit. In the case of extensive beef production where there is parent stock and the main focus in most cases is marketing of weaners the most efficient is to measure the amount of input resources needed to produce one kilogram of beef and to keep the parent stock productive. To measure economic sustainability of extensive beef production by commercial and communal farmers in South Africa the study used Cost Benefit Analysis by measuring environmental demand, efficient use of natural resources and productivity. Cost benefit analysis is one of the recommended tools to facilitate more efficient allocation of society's resources to help in social decision making. The resources are allocated efficiently when the benefit derived from the last unit of consumption is equal or more than the cost of production of that unit.

CBA involves identification and valuation of costs and benefits, analysis of financial aspects, economic aspects, risk and uncertainty of the project, then profitability or sustainability of the project can be determined by using NPV, IRR or C/B ratios. Financial analysis is carried to assess the profitability or financial sustainability of the project for the project owner and key stakeholders, taking into account only expenses and benefits that accrue to the project. Economic analysis appraises the project's contribution to the economic welfare of the country instead of just the owners of the project as in financial analysis. Economic analysis takes into account of external costs such as environmental costs and benefits. The major challenge when conducting farm level research in a large geographical area is gathering data in which to base the analysis. This is due to the complex and unique characteristics of each farm from other farms in many aspects. Few available options to obtain farm level data are highlighted as collection of individual data from farm to farm or sample of farms to be analysed, use of aggregate or state reported data or use of synthetic farms.

All these options have their advantages and disadvantages. The advantage of using individual farm data is that the analysis should adequately describe the farms being studied. However, individual farm data collection is time consuming and expensive to gather. Case studies are found to be indicative of the variability found in the target population rather than to be representative of the population, unless the farms were selected from the carefully selected designed random sample. Aggregating and averaging of agricultural production into a broad geographic and commodity output groups can mislead perceptions about the farm level economic aspects because there might be too much variation in resource structure and organisation such that the average farm might become an unrepresentative farm. The advantage of using aggregate data is that the data is relatively inexpensive to obtain. Synthetic farm offer an advantage of inexpensive data collection and data should not be biased by peculiar management one would find with sample data because it considers farms with minimum possible variability. It is stated that although synthetic farms may represent what should be a representative farm, they often overstate what actually is.

One suggested method of avoiding the possibility of average aggregate data is to develop sets of typical farms. Typical farms can be real or synthetic. The important characteristic of typical farms is that the resource base and the technological constraints are typical and are not the average of a group of farms. As a first step in conducting economic analysis, environmental demand and society benefits were determined. Analysis of typical farm provides the potential to more accurately gauge farm level impacts. The tool offers an advantage of relatively inexpensive data collection and data that is not biased to certain management practices as it could be the case with sample data. In estimating environmental demand three variables were used, namely, GHG emissions, biomass and water consumption. GHG emission for feedlot, extensive small scale and extensive commercial beef production, was estimated using published emission factors that are specific to South African conditions and management systems, national cattle population data and herd structure. Three main GHG emissions from livestock production, namely, N_2O and NH_4 from enteric fermentation and NH_4 from manure were estimated by multiplying the subgroup emission factors by the subgroup populations then summed across the subgroups and converted to $C0_2$ equivalent.

The amount of drinking water required to produce one kg of beef was estimated using an assumption of three to four litre water consumption per kg of dry mater intake. Three percent body weight dry mater intake was used in water consumption estimates as it is a recommended norm. The high energy proportion feed requirement in feedlots is assumed to be in the form of maize and other grains. Maize production water consumption of 250 litres per plant that produces 0,35kg of maize. Extensive beef farmers are assumed to be supplementing feed by 20% cultivated Lucerne. Lucerne production use 0,775 litres per kg produced. Then water demand for drinking and feed production were summed for each category of farmers. Biomass demand was estimated based on feed efficiency. Average daily gain and feed conversion ratio of an animal was calculated to determine biomass demand to produce one kg of beef. Average daily gain was computed as the final weight of an animal less birth weight divided by growth period. Feed conversion rate was calculated as average daily gain by daily feed consumption.

The results show higher GHG emission from the commercial extensive farmers compared to communal farmers, however when looking at GHG emitted per kg of meat produced per annum commercial sector emits less GHG per kg of live weight compared to communal farmers. For example in a communal sector a cow with an average weight of 360 kg emits 1.828 tons of CO_2 per annum, which is equivalent to 0.0051 tons of CO_2 per kg of live weight. In a commercial sector a cow with an average weight of 475 kg emits 2.315 ton of CO_2 per annum, which is equivalent to 0.0048 tons per kg of live weight. Extensive commercial beef farmers have been found to use more water compared to communal sector. The amount of water consumption depends on the feed consumption and weight of an animal, therefore these differences might be because of the difference in weight and feed consumption in these sectors and also the fact that commercial sector also make use of planted Lucerne. In a commercial sector a cow with an average weight of 475 kg consumes 19.011 m^3 of water per annum; therefore for each kg of live weight 0.04 m^3 is needed. In a communal sector a cow with an average weight of 360 kg consumes 13.797 m^3 per annum; therefore 0.038 m^3 is needed per kg.

An animal is assumed to consume 3% dry matter of its body weight per day. Animals with high body weight consume more feed, which in this study will be animals in commercial sector. The most important thing under this section is feed efficiency, which is defined as an amount of feed consumed by an animal converted to meat. If the birth weight of a calf in commercial sector is 35 and is reared for 214 days to reach weight of 190 kg, the average daily gain would be 0.72. To gain one kg weight the calf would need 7.87 kg of dry matter intake. A calf in the communal sector born with an average weight of 31.4 kg is reared for 336 days to reach weight of 152 kg. The average daily gain would be 0.36 per day and 12.70 kg of dry matter intake is needed to produce one kg live weight. Commercial sector uses feed more efficiently than in communal sector as more feed is needed in the communal sector to produce one kg than in commercial sector. This might be due to different factors such has the quality of feed, breed type, energy needed by an animal to reach feed and water per day, etc.

Typical farm budget models were developed as a tool for establishing and comparing the annual cost and benefits for both extensive commercial and communal farmers. In the development of typical farms; production systems, management level, population size, herd composition and their average weights, birth weight, market age, feed consumption, calving rate, mortality rate, take-off percentages were defined. Secondary data and literature was used to develop the typical farms. Environmental demand for each typical farm was estimated and valued. The beef sales were expressed as benefits for each typical farm. Biomass was valued at R871 per tonne and water at R2.00 per cubic metre (Blignaut *et al.*, 2017). CO_2 was valued at R120 per tonne (National Treasury, 2013). Scenario analysis was done by modelling three scenarios using typical farms developed as a base scenario. The second scenario assumed 15% management improvement resulting in 15% feed efficiency in both commercial and small scale farmer, improved calving percentage and take off percentages by the small scale farmer. In the third scenario efficiency improves by 20% and calving percentage by 40% in the communal farm and 62% in the commercial farm. The cost benefit ratios were calculated by dividing the value of sales by the value of environmental demand.

In a base scenario which represents the current farming practises, the estimated C/B ration is 0.96 showing that the environmental costs outweigh the benefits by 4%. This shows that the current production methods or management practises employed by commercial extensive farmers are not environmental sustainable. An improvement of in management practises that would result in efficiency of 15% average daily gain show a positive C/B of 1.01 which is equivalent to a gross margin of R11 011.59 in scenario two. An improvement in scenario three of calving percentage from 55% to 62% and take off from 32% to 36% and average daily gain by 20% would result in benefits of 1.12% equivalent to a gross margin of R127 326. A communal farmer with 19 cattle in scenario one has a C/B ratio of 0.15 showing a loss 85% equivalent to -R 41 213.38. An improvement in management practises resulting in increase of 15% in average daily gain, 40% calving rate, 32% take off and a decrease in mortality from 35% to 15% show an improvement in C/B ratio to 0.75 representing a short fall of 25% equivalent to a loss of –R13 043.89 per annum shown in scenario two.

A further improvement to 44% calving rate, 36% take off and 20% average daily weight gain still show a loss of 17% in scenario three. More improvement is needed by communal farmers to be environmentally sustainable. Sensitivity analysis of environmental sustainability against improved take-off and reduced environmental demand was also done. If the communal farmer can focus on increasing the take-off percentage only, to realise positive benefits seven animals will have to be sold per annum which is 37% take-off. When focusing on both decreasing the environmental costs and increasing take off percentage the benefits can be realised when the take-off is 32% and the environmental costs are lower by 10%. Both 5% increase in take-off and 5% decrease in environmental costs would results positive gross margin in the commercial farm. However benefits of decreasing environmental costs would be higher than of increasing take-off percentage only. If a commercial farmer increases take off by 5% to 135 units per annum the gross margin would be R10 620.20, with 5% decrease in environmental costs the gross margin would be R12 597.93.

The calculated B/C ratio for extensive commercial and Extensive beef production in South Africa is less than one. The results confirm that the extensive beef production in South Africa is not environmental sustainable in both small scale and commercial farmers. Improvement in management practices that would result in water and feed efficiency improvement would be more environmental beneficial than only improving take-off percentages. When conducting farm level research in a large geographical area, the type of data and the sampling method in which to base the analysis is a major challenge. Gathering data from individual farms or sampled farm to represent the country is time consuming and expensive. Economic analysis of typical farm allows the use of census data and other available secondary data. Typical farm analysis is recommended as a useful tool when doing farm level agricultural economic analysis studies.

The method of combining CBA and financial analysis proved useful and suitable for the study. Both the environmental demand, efficient use of resources and financial implications of commercial and communal beef production systems could be determined. The use of typical farms for the modelling process was time consuming and proved the potential of the combination of CBA and financial analysis. The sensitivity analysis also added the benefit of showing where in each system possible improvements can be made.

5.2. Summary

In South Africa 80% of the terrestrial land surface is utilised for agricultural purpose with almost 70% suitable for extensive grazing. Natural resources are currently under stress, and with the world projected population increase of nine billion inhabitants by 2040 the beef consumption is projected to increase by 20% in year 2024. The increase in demand for food and fibre will have additional environmental consequences. Such environmental demands include GHG emissions, biomass and water consumption. In agriculture livestock has been recognised as the largest contributor to climate change in South Africa, cattle farming contributing 76% of the total emissions though GHG emissions. The livestock sector is required to reduce GHG emission by 20% in 2025 to meet South Africa's global commitments to reduce emissions. Climate change puts more pressure on the country's scares natural resources such as water and the quality of land resulting in negative performance of the agricultural sector. A number of studies confirmed that extensive beef production has more environmental demand compared to intensive beef and dairy production.

The beef industry in South Africa is dualistic with commercial and non-commercial (small scale and subsistence) farmers. Environmental demand and efficiency for different categories of beef farmers under different production systems was investigated with main focus on extensive beef production. The purpose of this study was to assess the economic sustainability of extensive beef production at different categories of farmers or different production levels. This objective would be achieved by measuring GHG emission, water use and fodder consumption and explore possibilities and options to improve efficiency of water and fodder consumption and reduction of GHG emission per kilogram of beef produced. In assessing economic sustainability of extensive beef production by small scale and commercial farmers in the country, cost benefit analysis of typical farms was proposed as a methodology to be used. Cost benefit analysis is defined as a systematic process for calculating and comparing costs and benefits of a project to the community as a whole and valued in today's dollar. A typical farm is defined as a tool that can be used to assess farm profitability and to determine the effect of variation in a range of variables on farm profitability.

In chapter two, industry overview and review of methods is discussed. Approximately 80% of South African agricultural land is suitable for extensive grazing. Livestock is the largest in agricultural sector, contributing 47% in the total production value of agricultural sector in 2017. The beef industry is the second fastest growing commodity in agricultural sector following the broiler sector. Cattle numbers have been above 13 million since 1996 and 80% of the total cattle heads is beef cattle. During 2013/14 to 2016/17 production has been higher than consumption and this makes South Africa self-sufficient as beef production satisfies the local demand during the said period. Due to increased consumption and population beef prices have been increasing since 2008. South African primary beef production is unique due to its dualistic nature of commercial and non-commercial farmers. Commercial farmers are well established farmers mostly with large pieces of land and Communal farmers which in this study include both subsistence and small scale farmers are farmers that individually own small numbers of livestock and use communal grazing land or small pieces of leased land.

The majority of beef cattle is marketed through the feedlot industry. A feedlot is a confined area where animals are hand or mechanical fed to produce consistent quality meat. Feedlot purchase weaner calves ranging from 160 to 260 kg weight and feed them to an average market weight of 450 kg. Different production systems are used to raise livestock namely, extensive, intensive and mixed production system. In extensive beef production livestock depend primarily on natural vegetation. On mixed production system, animals graze on natural vegetation and cultivated pastures. Intensive production system is dominated by commercial farmers producing under feedlot system. The South African beef industry is faced with a challenge of increasing beef production to meet the growing demand, adapt to changing economic and natural environment, and the need to improve its environmental performance. The focus of the study was environmental demand by beef production in South Africa.

Agriculture is closely tied to climate change and globally agriculture is said to be responsible for about 14% of all GHG emissions. Livestock has been identified to carry large amount of carbon foot print compared to other foods. Cattle are ring fenced as the major sources of NH_4

emissions from the livestock sector in South Africa, contributing 72.6% of the total livestock GHG emission. CH_4 has a global warming potential of 25 times than that of CO_2, and N_2O has a global warming potential of 289 times than that of CO_2. Extensive beef production has been identified by Du Toit *et al*., (2013) as the largest contributor to the cattle sector's GHG emissions, commercial sector contributing 54.7% and informal sector contributing 28.6%. Climate change also has direct and indirect effects on livestock production. Extreme and rapid changes in environmental conditions compromise reproductive efficiency of farm animals and negatively affect productivity. There are suggested options for livestock farmers to mitigate and adapt to climate change such as, reduction in animal numbers, improving production efficiency, implementation new climate smart production systems are also suggested to reduce GHG emission and adapting to climate change. Sustainable agricultural practices are recommended as best possible option to adapt and mitigate climate change challenges while improving productivity.

There is no single way of securing sustainability, livestock production system differ widely in terms of use of resources, degree of intensification, species and orientation of production, regional socio-economic, market context and cultural roles. Sustainable beef farming principles covering economic, social and environmental sustainability are identified by SAI Platform Beef Working Group to guide the beef farmers towards sustainable beef production. These principles clarify the norms for further use in this thesis. A large number of studies about the impact of livestock on environmental sustainability was conducted globally. Most of these studies estimated higher GHG emission on extensive cattle production system compared to intensive cattle production. Extensive beef production system include commercial and communal farmers using different management practises. This study assessed economic sustainability of each category of farmers in extensive production system.

Chapter three describes methods and material used in the study. The chapter describes the methodology. Cost benefit analysis and typical farm models were used in assessing the economic sustainability of extensive beef production in South Africa. A cost-benefit analysis is defined as a systematic process for calculating and comparing benefits and costs of a project in today's dollars to society as a whole. The purpose of cost-benefit analysis (CBA) is to help social decision making and to facilitate more efficient allocation of resources. CBA involves the identifying and valuing of costs and benefits of the project; analysis of financial aspects, economic aspects and risk and uncertainty of the project. Analysis of financial aspect is made from the perspective of a person, group or unit directly involved in the farm business. Only expenses that will be made by the farm and benefits that will accrue to the farm are taken into account in a financial analysis. Economic analysis is done on behalf of the whole society instead of just the private individuals. In economic analysis all costs and benefits are taken into account, including externalities. Even if the project entity does not pay for the use of a resource that does not mean that the resource is a free good. The financial prices are adjusted to reflect the value to the society as a whole of both inputs and outputs of the project.

Costs are described as the intended or unintended negative effects of a project. Benefits are described as the intended or unintended positive effects of a project. Once the costs and benefits are identified, they are valued at their opportunity cost. Generally the use of market prices is recommended as they best reflect the opportunity cost involved. The value of opportunity cost is usually reflected in its market price, if they are not reflected due to market distortions, the recommended approach is to convert market prices into shadow prices. If some costs cannot be quantified in physical or monetary terms, these should still be noted, and given some weighting which reflects their importance. Once all project cost and benefits are quantified and valued in money terms, the economic performance is measured by calculating net present value or benefit cost ratio or internal rate of return. Positive NPV and C/B ratio greater or equal to 1 indicates a positive net benefit. In case of mutual exclusiveness the project with the highest (positive) NPV is favoured, other things being equal. IRR is the maximum interest that the project could pay for resources used if the project is to recover its investment and operating costs and still break-even.

Uncertainty and risk are present whenever a project has more than one possible outcome. Risk assessment is required to deal with the uncertainty that always permeates investment projects, including the risk that the adverse impacts of climate change may have on the project. In some circumstances there is just uncertainty, but in other cases this can be transformed into risk with an assessment of probability distributions indicating the likelihood of the realised value of a variable falling within stated limits. The recommended steps for assessing the project risk include sensitivity analysis, probability distributions for critical variables, risk analysis, assessment of acceptable levels of risk and risk prevention. The major challenge when conducting farm level research in a large geographical area is gathering data in which to base the analysis. This is due to the complex and unique characteristics of each farm from other farms in many aspects. Few available options to obtain farm level data are highlighted as collection of individual data from farm to farm or sample of farms to be analysed, use of aggregate or state reported data or use of synthetic farms.

All these options have their advantages and disadvantages. Aggregating and averaging of agricultural production into a broad geographic and commodity output groups can lead to misleading perceptions about the farm level economic aspects because there might be too much variation in resource structure and organisation such that the average farm might become an unrepresentative farm. The advantage of using aggregate data is that the data is relatively inexpensive to obtain. One suggested method of avoiding the possibility of average aggregate data is to develop sets of typical farms. Typical farms can be real or synthetic. The important characteristic of typical farms is that the resource base and the technological constraints are typical and are not the average of a group of farms. Analysis of typical farm provides the potential to more accurately gauge farm level impacts. The tool offers an advantage of relatively inexpensive data collection and data that is not biased to certain management practices as it could be the case with sample data. As a first step in conducting economic analysis, environmental demand and society benefits were determined. In estimating environmental demand three variables were used, namely, GHG emissions, biomass and water consumption.

Chapter four discusses the application of the methodology and analysis of results. The methodology is divided into three sections, namely; input data, Calculation and Output. The input data was sourced from secondary data and literature. Calculations include GHG emission, water consumption fodder consumption, valuing of costs and benefits. The output is environmental demand of the beef industry calculated as per category of farmers, typical farm budgets to calculate cost benefit ratio and do scenario analysis. GHG emissions calculation are based on 2006 IPCC guidelines for National greenhouse Inventories. Emission factors specific to the South weather conditions and management systems, national cattle population data, and herd structure sources from the secondary data were used. Water use was calculated based on the recommendations of 3, 5 litre consumption per kg of dry matter intake and feed intake is assumed to be 3% of animal body weight per day. Extensive commercial farmers are assumed to be supplement feed by 20% with Lucerne. Lucerne production requires 0.775 litres to produce 1 kg. The amount of feed needed to produce 1 kg of beef was estimated by calculating the ADG and FCR. Typical farm profiles for extensive communal and commercial farmers were then developed using secondary data and literature and environmental costs and benefits were valued.

The environmental demand analysis was done, budget models for the typical farms were developed to calculate the C/B ratios, scenario and sensitivity analysis was done and results were discussed. The results show that extensive commercial farmers have higher total GHG emission demand compared to extensive communal farmers, however commercial farmers demands less GHG per kg of live weight compared to communal farmers. More water is used by commercial compared to communal sector. In average each animal in a communal sector consumes 11.238 m^3 and 19.520 m^3 per annum in a commercial sector. These differences might be because of the difference in weight and feed consumption in these sectors and also the fact that commercial sector also make use of planted Lucerne. Feed consumption depends on the weight of an animal. Animals with high body weight consume more feed, which in this study is animals in the commercial sector. The most important thing under this section is feed efficiency. If the birth weight of a calf in commercial sector is 35 and is reared for 214 days to reach weight of 190 kg, the average daily gain would be 0.72. A calf gain one kg weight would need 7.87 kg of dry matter intake. A calf in the communal sector born with an average weight of 31.4 kg is reared for 336 days to reach weight of 152 kg. The average daily gain would be 0.36 per day and 12.70 kg of dry matter intake is needed to produce one kg live weight.

Commercial sector uses feed more efficiently than the communal sector as more feed is needed in the communal sector to produce one kg than in commercial sector. This might be due to different factors such as the quality of feed, breed type, energy needed by an animal to reach feed and water per day, etc. the base scenario in the developed typical farm budgets show that both commercial and communal extensive beef production is not environmental sustainable. The B/C ratios are less than one, with environmental costs out weighing benefits by 4% in commercial farmers and by 85% in communal farmers. More improvement in production practises is needed by communal farmers to be environmentally sustainable compared to commercial farmers. Sensitivity analysis on take-off percentage and environmental demand was done. The results show that it would be more beneficial to reduce environmental demand than increasing take-off percentages. In conclusion, the current production methods both in commercial and small scale / communal farmers are not environmental sustainable as the environmental costs are higher than the benefits. Farmers need to employ production methods that will improve the efficient use of resources to improve environmental sustainability.

5.3. Recommendations

Beef cattle production has been increasing due to the increasing protein demand worldwide, At the same time, the need to reduce overall environmental footprint became the top priority in the world. The beef demand is projected to increase by 30% in 2030, and this will have additional environmental consequences. Environmental demand in this paper include GHG emission, fodder and water consumption. Livestock farming is required to reduce GHG emission by 20% in 2025 to meet the South Africa's global commitment to reduce such emissions. Cattle is said to be a major contributing source of CH_4 emission from the livestock sector in South Africa. A number of studies concluded that extensive beef production has higher environmental demand compared to intensive beef production. Extensive Beef production in South Africa is produced by different categories of farmers that differ in management practices and access to resources. Therefore it is paramount important to assess the environmental demand and production efficiency by different categories of extensive beef farmers.

Cost Benefit Analysis of typical farms was used to assess the economic sustainability of commercial and communal extensive beef production in South Africa. CBA is recommended to be used when the benefits or costs are difficult to quantify. It provides a systematic way of comparing the costs and benefits of a project to promote efficient allocation of resources. CBA is an effective methodology to measure environmental efficiency in monetary terms in order to have an idea of the monetary value of the impact the project to the environment. Sourcing data for farm level research in a large geographical area can be costly, time consuming and can sometimes result is biased results. Each farm is unique in many aspects and profitability cannot be affected by same effects precisely in the same manner irrespective of the farm size. Use of typical farm analysis is recommended to avoid the average bias results when aggregate data is used and it is cost and time efficient as it allows the use of census and secondary data. Typical farm model takes into consideration of typical resource base, technological constraints, the common mix of enterprises, combination of capital items required for production and size of the farm. It is recommended to use typical farm as a tool to evaluate and compare the effects of various management practices and of paramount importance to take into account of typical characteristics of the farms to avoid having a biased representative farm. In this study the size of the farm, category of farmer, type of production system.

Conducting the study of this nature for other animals would assist in determining which production system and category of farmers is using natural resources more efficiently. A study that would identify the breeds that have high feed conversion ratio and draught tolerant is recommended. A policy and intervention that would encourage communal farmers to view farming as a business would assist in reducing carbon foot print from communal farmers.

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